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AFFINITIES OF THE GENUS EQUISETUM.

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THE genus Equisetum, as the survivor of an ancient race, which has otherwise completely disappeared, is of peculiar interest to the botanist. It is not strange that numerous attempts have been made to trace its history, and to determine its relationships to the other pteridophytes, recent and fossil.

The existing species of Equisetum, about twenty-five in number, are distributed over nearly the whole world — Australia alone, among the larger bodies of land, has no species in its flora. Some species, *e. g.*, *Equisetum arvense*, have a very wide range, while others, like *Equisetum giganteum*, are confined to a smaller area. The genus is sometimes subdivided, but the differences are of minor importance, and more commonly all the species are relegated to the single genus Equisetum.

There is a general agreement in the anatomical structure, perhaps the most marked difference being the variation in the relation of the endodermis to the vascular bundles. Thus, in certain species, like *Equisetum telmateia*, the ring of vascular bundles in the internodes is surrounded by a common outer endodermis, while in others, *e. g.*, *Equisetum hiemale*, each strand has its own sheath; while in a third type, represented

by *Equisetum silvaticum*, there is an inner as well as an outer endodermis, common to the whole circle of bundles. Other differences are the presence or absence of branches at the nodes, and the development in certain species, like *Equisetum arvense*, of special sterile and fertile shoots.

Fossil Equisetales.

The earliest fossils belonging to the Equisetales belong to the genus Archæocalamites, which in many respects was very similar, as regards both its anatomy and fructification, to the genus Equisetum. Fossils of undoubted equisetinean affinities abound in the later Palæozoic formations, being especially abundant in the coal measures. Of these, the genus Calamites was especially conspicuous. These were much more highly organized than the living Equiseta, which more nearly resemble the more ancient Archæocalamites. Fossils closely allied to the genus Equisetum occur frequently, however, in later formations, being abundant in the earlier secondary rocks.

Undoubtedly related to the Equisetales was the characteristic Palæozoic group of Sphenophyllales, but there is a good deal of diversity of opinion as to the possible connection of the Sphenophyllales with other groups of pteridophytes besides the Equisetales.

The genus Equisetum has been the subject of repeated investigation, and we are now well informed concerning pretty much all its structural details and developmental history. The conclusions drawn from a study of these data by different observers, however, are by no means all in accord. This difference is especially marked in the attempts to decide the affinities of the Equisetales with the other pteridophytes. It is mainly for the purpose of examining and comparing these divergent views that the present paper has been prepared.

Briefly stated, the following are the different views held as to the relationships of the Equisetales :—

1. They are allied to the lycopods.
2. They are allied to the ferns.
3. They are allied to neither of the other existing classes of pteridophytes, but have had an independent origin.

The first view has been strongly advocated by Scott[1] in England, who bases his conclusions upon a study of the fossil forms. In America, Jeffrey[2] has brought forward arguments in favor of the same view, from a study of both the gametophyte and sporophyte. He goes so far, indeed, as to propose a special division of the pteridophytes into the Lycopsida, and Pteropsida, the former including both Equisetales and lycopods, the latter the ferns.

As he has presented his arguments in very clear form, it may be well to consider them somewhat in detail, to see how they will stand the test of closer examination.

From a study of the gametophyte of Equisetum,[3] Jeffrey concludes that it most nearly resembles the gametophytes of such species of Lycopodium as *Lycopodium cernuum* or *Lycopodium inundatum*. "There are in both cases, the upright fleshy axis, and the same characteristically numerous lateral lobes. The archegonia of Equisetum and Lycopodium are, moreover, alike, in that in both genera they are uniformly without the basal cell, which is found without exception in the archegonia of all the isosporous Filicales" (*loc. cit.*, p. 186). He finds also that the neck canal cell is divided vertically as in *Lycopodium phlegmaria*, instead of transversely as is the case in the ferns.

Finally, in the embryo of *Equisetum hiemale* and *Equisetum limosum*, Jeffrey thinks that all the organs of the young sporophyte, including the primary root, develop from the upper or epibasal half of the embryo, in this respect also, showing a resemblance to the Lycopodiales.

The points in which the adult sporophytes of Equisetum and Lycopodium agree, are the highly developed axis, and small leaves; the development of a strobilus, and the so-called "cladosiphonic" vascular cylinder, or stele. It is on the basis of these resemblances that Jeffrey proposes the establishment of his micro-

[1] *Studies in Fossil Botany* — as well as many special papers.

[2] 1. The development, structure and affinities of the genus Equisetum. *Mem. Boston Soc. Nat. Hist.*, 1899; 2. Structure and development of the stem in the Pteridophyta and Gymnosperms. *Phil. Trans. Royal Soc.*, series B, vol. 195, 1902.

[3] Jeffrey, 1, p. 186.

phyllous and cladosiphonic Lycopsida, opposed to the megaphyllous, phyllosiphonic Pteropsida.

In his comparison of the gametophyte of Equisetum with that of Lycopodium, Jeffrey has overlooked a radical difference, to which Gœbel [1] has called attention, and which has been noted by other investigators. In the former genus, the gametophyte is dorsiventral, as it is in the ferns, and the archegonia originate

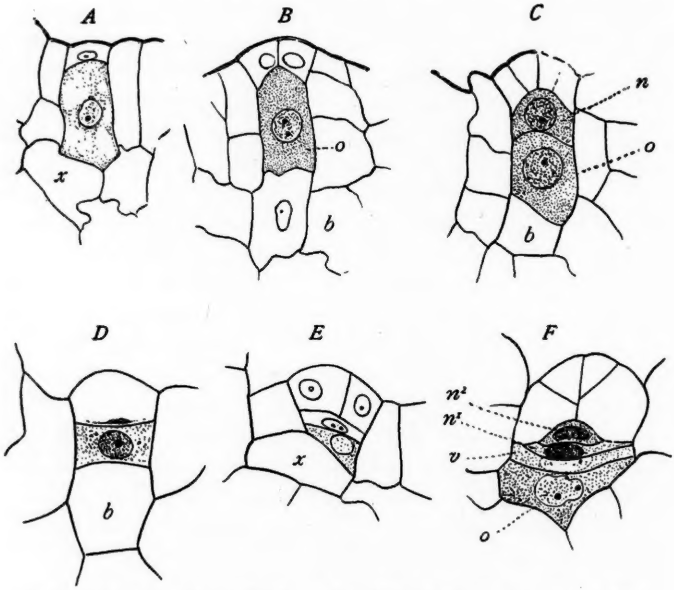

FIG. 1.—*A–C*, young archegonia of *Marattia douglasii*; *D–F*, young archegonia of *Equisetum telmateia*; *b*, basal cell; *x*, basal cell cut off before the isolation of the mother cell of the archegonium.

upon the ventral or shaded surface, the more or less conspicuously upright position being dependent upon light. The position of the archegonia upon the upper side of the prothallium is a secondary condition.

In Lycopodium the prothallium is radially constructed, the lobes being arranged equally about the upper part. The growth

[1] *Organographie der Pflanzen.* Zweiter Theil, Heft II, p. 409.

is marginal, and the meristem completely surrounds the upper part of the thallus, there being no proper apical growth as in Equisetum.

The gametophyte of Equisetum can much more properly be compared with that of the lower ferns like Osmunda or Marattia,

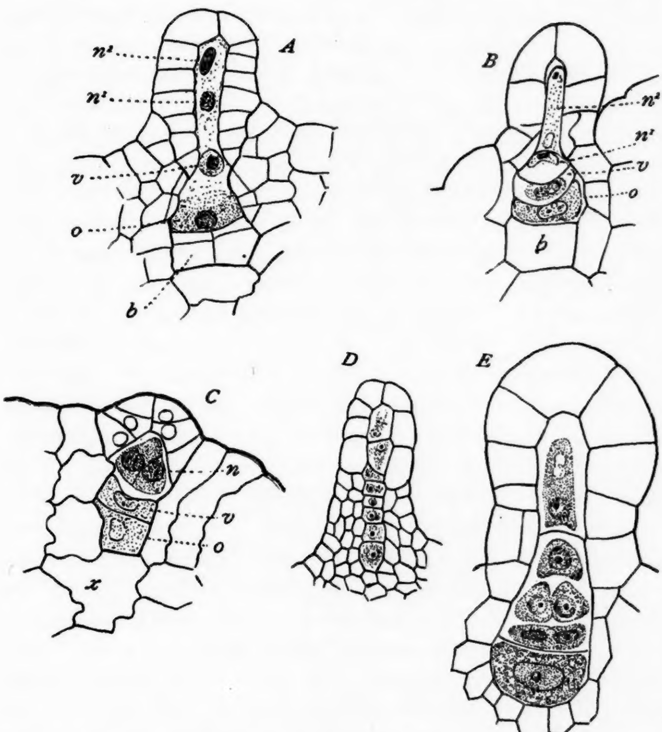

FIG. 2.—*A*, archegonium of *Botrychium virginianum*; *B*, *Equisetum telmateia*; *C*, *Marattia douglasii*, showing longitudinal division of the neck canal cell; *D*, *Lycopodium clavatum*; *E*, *Lycopodium phlegmaria*; *b*, basal cell; *o*, egg cell; *v*, ventral canal cell; *n*, *n'*, neck canal cells. (*D*, after Bruchmann; *E*, after Treub.)

and in the former genus especially there are sometimes developed lobes not essentially different from those found in the gametophyte of Equisetum.

As to the presence or absence of the basal cell of the arche-

gonium, this is probably not a point of fundamental importance. The writer has taken the trouble to examine this point somewhat carefully in *Equisetum telmateia*, *Marattia douglasii*, and *Osmunda cinnamomea*. In the former, an unmistakable basal cell was found in several instances (Fig. 1, *D*), although there is no question that ordinarily it is absent. Jeffrey states that in the species examined by him, it is universally wanting. In Marattia it was generally present, but much less conspicuous than in most ferns. Not infrequently, however, it was entirely wanting, as according to Jonkman (*Bot. Zeitung*, 1878), it is in the species of Marattia examined by him. Farmer says that in Angiopteris it is also absent.[1] In *Osmunda cinnamomea*, while ordinarily present, it may be wanting.

It is thus evident that too much stress cannot be laid upon the presence or absence of the basal cell. It is probably no more important than the pedicel in the archegonium of the Marchantiaceæ. *Marchantia polymorpha*, for instance, regularly develops such a pedicel cell, while in Targionia and Fimbriaria, it is regularly absent, and the archegonium is closely sessile.

An interesting condition was noted in several cases in Equisetum (Fig. 1, *E*) where a basal cell was developed before the final cutting off of the mother cell of the archegonium. An exactly similar case was found in Marattia (Fig. 1, *A*).

Jeffrey has described a peculiarity in the archegonium of Equisetum which he thinks points to a relationship with Lycopodium as in one species, *Lycopodium phlegmaria* (Fig. 2, *E*), a similar condition has been found. This is the longitudinal division of the neck canal cell. To judge from my own preparations of *Equisetum telmateia*, this rarely occurs in that species, where the division wall is normally transverse, as it is in the ferns (Fig. 1, *F*), and most other Archegoniates. A similar longitudinal division has been observed in species of Isoetes.[2] In one instance a similar longitudinal division was found in Marattia (Fig. 2, *C*).

To summarize: it seems to the writer that in all respects

[1] *Annals of Botany*, vol. 6, 1892.

[2] Arnoldi, *Bot. Zeit.*, 1896; Lyon, *Bot. Gazette*, 1904.

there is decidedly more resemblance between the gametophyte of Equisetum and that of the lower ferns than there is between it and any species of Lycopodium.

The Embryo.

According to Sadebeck,[1] who has made a special study of the embryo of Equisetum, the primary or basal wall of the embryo, which is transverse, divides the embryo into an upper or epibasal cell, and a lower or hypobasal one. From the epibasal cell is derived the apex of the shoot; from the hypobasal one the foot and the primary root. My own studies upon *Equisetum telmateia*, although not complete, confirm Sadebeck's statement. Jeffrey[2] thinks it doubtful whether the root in *Equisetum hiemale* and *Equisetum limosum* originates from the hypobasal region of the embryo, but to judge from his figures 7, 8, it is by no means certain that his interpretation is correct. While comparing the embryo of Equisetum with that of Lycopodium, in which all of the organs of the embryo arise from the epibasal half, he fully recognizes the fact of the presence of the suspensor in the lycopods, and its absence in Equisetum. Even if his assumption of the epibasal origin of the root were correct, it could more aptly be compared with the embryo of Botrychium, where he has shown[3] that both root and shoot are of epibasal origin, and moreover, the cotyledon develops secondarily from the shoot as the first foliar sheath does in Equisetum.

The Mature Sporophyte.

The sporophyte of Equisetum, as is well known, differs widely in its general structure from either the ferns or lycopods. The structural type as it exists in the living horsetails is evidently a very ancient one, and the oldest fossils belonging to the Equisetales are not essentially different in their structure from the living species.

[1] *Bot. Zeit.*, 1877.
[2] *Loc. cit.*, p. 169.
[3] The Gametophyte of Botrychium. *Proc. Canad. Institute*, vol. 5, 1898.

The hollow jointed stem, the remarkably regular apical growth of both shoot and root, and the structure and arrangement of the vascular bundles are very different from the lycopods with which it has been attempted to connect the Equisetales. It is true that both the latter class and the lycopods are characterized by relatively small leaves, but their structure and relation to the shoot are very different in the two classes.

It may be questioned whether the excessive reduction of the leaves found in most species of Equisetum is not a secondary condition. The oldest known type, Archæocalamites, while agreeing closely in its general structure with Equisetum, differed in the very much better developed leaves, which not only were much larger than those of Equisetum, but were repeatedly branched in a dichotomous manner, more suggestive of the leaves of certain ferns than of any forms among the lycopods. Their relation to the shoot, however, was precisely that of the existing forms. The peculiar extinct order, the Sphenophyllales, which are admittedly of equisetaceous affinities, also possessed dichotomously divided leaves, or wedge-shaped leaves with dichotomous venation.

The fact that both Equisetales and lycopods have the sporangial structures arranged in a strobilus or cone, can hardly be taken as a necessary indication of relationship. The structure of the cones in the two classes is very different, the sporangiophores of Equisetum being hardly comparable to the true sporophylls of Lycopodium. Moreover, true strobili are known in the fern series, as shown by the cycads, whose relationship with the ferns is now almost universally admitted.

While the structure of the sporangia and of the spores is extremely characteristic in Equisetum, the development of the sporangium is much more like that of the eusporangiate ferns than like that of any of the Lycopodineæ.

Jeffrey lays much stress upon the arrangement of the vascular bundles in Equisetum, which he thinks can be compared better to those of the Lycopodiales than to those of the ferns. Van Tieghem,[1] on the other hand, refers Equisetum to his

[1] *Traité de Botanique.*

"astelic" type, to which Ophioglossum also belongs. Whether or not Equisetum is astelic in Van Tieghem's sense, there is a very important respect in which it differs from the other pteridophytes that have been critically studied, namely, the origin of the vascular bundles from the cortical region, and not from the primary central cylinder. A longitudinal section of the shoot shows an early differentiation into a central cylinder and cortex, but it is from the latter and not from the former that the vascular strands originate, the central cylinder developing only the pith.

Jeffrey in his study of the development of the vascular system in the young sporophyte does not state whether the relation of the vascular strands to the primary central cylinder is the same as in the adult sporophyte, but there is no reason why it should be different, as otherwise the arrangement of the bundles is the same.

He states that the arrangement of the bundles in the primary shoot is the same as in the later ones, except that he finds at the base of the shoot below the first leaf sheath, a closed ring of vascular tissues, such as occurs at the nodes, and considers this as a remnant of a primitive cylindrical stele or vascular cylinder; but it is not quite clear why this does not simply represent the first node where we should expect to find essentially the same arrangement of the tissues as in the later nodes.

As in the later shoots, there extend between the nodes separate vascular strands corresponding in number to the teeth of the leaf sheaths,— three as a rule in the primary shoot. These fork at the nodes, and each branch joins one from the neighboring bundle, so that the vascular strands alternate in succeeding internodes as they do in the later formed shoots.

In Archæocalamites, the earliest known type, the bundles are continuous from one internode to another, but in the Calamites of the Carboniferous, the same arrangement is found as in Equisetum.

Jeffrey considers the spaces between the internodal strands as gaps in an originally continuous cylinder, comparable to the large foliar gaps found in the cylindrical stele of the ferns, or the ramular gaps, occurring where branches are given off, in the

lycopods. From a study of the fossil Equisetales, especially Archæocalamites, he concludes that these gaps are to be considered as ramular gaps, although he admits that in Equisetum they occur opposite the leaves. He proposes the term "cladosiphonic" to designate a cylindrical stele, with ramular gaps, such as he assumes for the Equisetales and Lycopodiales.

Admitting that the vascular system of Equisetum can be referred to a siphonostelic type, it is hard to see how we can reconcile Jeffrey's idea of cladosiphony with the facts. So far as we can see there is absolutely no difference in the arrangement of the bundles of the internodes and their intervening spaces in shoots which develop branches, and those which are without them. In all cases, the number of internodal strands — and, of course, that of the gaps between them — corresponds to the number of leaf traces developed from the foliar sheath. The gaps are equally present in the primary unbranched shoot, and in the densely branched sterile shoots of *Equisetum arvense* or *Equisetum telmateia*. It certainly seems hardly reasonable to suppose that an ideal branch — so to speak — could cause the development of a ramular gap, when no actual branch is present.

Jeffrey lays stress upon the fact that in Archæocalamites, the branches are really opposite the spaces between the internodal vascular strands; but it appears [1] that Archæocalamites was often very sparingly branched, but this does not seem to bear any relation to the presence of the alleged ramular gaps, which are perfectly developed whether branches are present or not.

We see no reason why we should try to reduce the vascular system in the Equisetales to either of the types found in the other phyla of pteridophytes. The peculiar character of the stem, with its hollow jointed structure, would naturally involve quite a different arrangement of the tissues. Moreover, as has already been indicated, the origin of the vascular strands is entirely different from that of the typically axial vascular cylinders of the other classes. There is no valid reason why the separate strands in Equisetum may not have existed from the

[1] Scott, *loc. cit.*, p. 65: Potonie, *Lehrbuch der Pflanzenpalæontologie, 1899.*

first. The oldest fossils show the same type, and in the embryo, before any trace of the vascular bundles can be seen, there is developed the three-leaved primary foliar sheath, and corresponding to the three teeth of the foliar sheath, are developed simultaneously the three vascular strands of the first internode.

The Sphenophyllales.

The Sphenophyllales are exclusively fossil forms which show evident affinities with the Equisetales, from which they differ especially in the arrangement of the tissues of the stem. Instead of the large central cavity found in the stem of Equisetum, Sphenophyllum has an axial solid vascular cylinder more like that of the modern lycopodiaceous forms than like any other existing pteridophytes.

Scott[1] considers that the Sphenophyllales are to some extent intermediate between Equisetales and Lycopodiales, basing his opinion mainly upon the anatomical characters, especially those of the stem. The peculiar fossil Cheirostrobus[2] he especially considers a synthetic type, having the sporangia of the Equisetum type, but the vascular system of a lycopod.

Potonie[3] holds that the Sphenophyllales are an early offshoot of the equisetaceous series, perhaps directly connected with Archæocalamites. The characteristic triarch or hexarch bundle of the stem suggests a three-sided apical cell like that of Equisetum, but in the Psilotaceæ, which are commonly associated with the Lycopodiales, there is a somewhat similar type of stele, and these forms also have a single tetrahedral initial cell in the shoot.

One objection to considering the Sphenophyllales a synthetic type is that all the existing types of pteridophytes were clearly differentiated in formations earlier than any in which remains of the Sphenophyllales certainly occur.

[1] *Studies in Fossil Botany*, 1900.
[2] *loc. cit.* pp. 106–114.
[3] *loc. cit.*, p. 180.

The peculiar, jointed, hollow stem, with the characteristic arrangement of the bundles, except for their alternation in succeeding internodes, is as marked in the earliest Equisetales as it is in the existing genus, and cannot readily be derived from either the type of the ferns or lycopods, both of which are clearly recognizable in the formations where they first occur. So far as we can judge from the geological record, the central solid stele of Sphenophyllum is a more recent development than the separated vascular strands of the typical Equisetales, as exemplified by Archæocalamites.

CONCLUSIONS.

As we have endeavored to show, the gametophyte of Equisetum resembles that of the eusporangiate ferns rather than Lycopodium, both in its dorsiventral character, and method of growth, and especially in the large multiciliate spermatozoids. We believe that these resemblances indicate a real, although extremely remote, relationship with the lower ferns.

The early divisions of the embryo are not unlike those in the fern embryo, but the early preponderance of the shoot, and the subordination of the leaves, very soon produce an extremely different type of sporophyte, and it is highly probable that the peculiarities of the sporophyte were established at a very remote period, and are not modifications of another type. The dichotomously divided leaves of the older Equisetales and Sphenophyllales are somewhat reminiscent of those of some ferns, although it is not at all likely that there is any direct genetic relationship between these.

The most probable conclusion to be reached, in view of the evidence at hand, would seem to be that the two series, the ferns and Equisetaceæ, are descended from a common stock, in which the gametophyte was not unlike that of the existing species of Equisetum and the lower eusporangiate ferns. It must be assumed, however, that the peculiarities of the sporophytes became established at so remote a period that one cannot say that either was derived from the other — *i. e.*, from the same ancestral stock represented by the gametophyte as it now exists

in the two classes, there arose quite independently two types of sporophyte: one distinguished by a preponderant development of the shoot, the other marked by the great development of the leaf structures.

Neither of these classes is at all related to the Lycopods, which show strong evidences of being derived independently from a very different type of gametophyte.

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MOVEMENTS OF DIATOMS AND OTHER MICROSCOPIC PLANTS.

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FEW subjects in the domain of cryptogamic botany have given rise to more speculation and conflicting theories than have the studies into the cause of the apparently voluntary movements of diatoms. From time to time for the past twelve years the author has been confronted with this seemingly fruitless subject, and only recently, almost by accident, has the problem been solved.

It was early shown by examination in closed cells that the phenomenon was not due to external currents set up in the surrounding liquid, but that the power of motion came from the organism itself. Largely on account of these movements, which appeared to be spontaneous and voluntary, the diatoms were originally classed in the animal kingdom.

The first theory which naturally presented itself was that they move as do the Infusoria by means of vibrating hair-like cilia or flagella. Later certain authors claimed to have seen protoplasmic processes similar to those of the rhizopods protruding from the small openings in the frustule of the organism. Then came the theory of Onderdonk [1] which described the progression as due to a thin fluid mass in rhythmical motion covering the surface of the diatom.

Nägeli suggested that the motion is due to endosmotic and exosmotic currents, and H. L. Smith [2] after much study of the subject came to the conclusion "that the motion of the Naviculæ is due to injection and expulsion of water, and that these currents are caused by different tensions of the internal membranous sac in the two halves of the frustules."

[1] The Movements of Diatoms. *The Microscope*, August, 1890.

[2] A Contribution to the Life History of the Diatomaceæ. *Proc. Amer. Soc. Microscopists*, 1888.

In order to prove this theory, Professor Smith showed by means of suspended indigo that when the diatom moves forward the particles of indigo gather around the central nodule of the valve and form a small mass which turns on itself just as if it was impelled by a jet of water proceeding from the valve at this point. Each of these little turbulent spheres after having acquired a certain size, falls apart and the particles which compose it are driven along the valves from front to back and accumulate behind the extremity of the frustule which, according to its progression, would be considered the rear. The particles move as if they were subjected to a current going from front to back, and reverse when the motion is reversed. That these currents exist there can be no doubt, but that the motive power is not due to the expulsion of water will shortly be demonstrated.

The first intimation of the true nature of this motion was suggested by the action of a lithia tablet in a glass of water. The bubbles of carbonic-acid gas given off set up the exact motions in the tablet that have been so often described for the movements of diatoms: "A sudden advance in a straight line, a little hesitation, then other rectilinear movements, and, after a short pause, a return upon nearly the same path by similar movements."

Repeated experiments with compressed pellets evolving gas have shown that this is the usual motion produced by the evolution of gas bubbles, and when pellets were made of the same shape as Navicula the movements of these diatoms were perfectly duplicated. Boat-shaped pieces of aluminum two millimeters thick were then made and on them were cut longitudinal grooves to resemble those of the diatom. When placed in strong caustic soda solution the movements of the metal produced by the evolution of hydrogen gas again duplicated those of the diatom in a remarkable manner. The metal having the grooves had a greater power of motion than that without the grooves.

If we consider that the diatom contains chlorophyll bands which when exposed to a strong light rapidly evolve oxygen, and if we take into account the fact that the motion does not take place unless the light is fairly strong, we have then a conception of the true nature of the movements of these organisms.

Streams of oxygen may be readily seen evolving from all parts of many of the larger aquatic plants when submerged in water and exposed to strong light, but in the diatom while the gas produced is large in amount compared with the size of the organism, the actual amount evolved is so small that it is taken into solution almost immediately. That such evolution takes place, however, is shown by Professor Smith's experiments with indigo. If now we examine the artificial diatom made of aluminum and placed in strong caustic solution we find that the bubbles from all sides come together and rise in a line corresponding to the median line or raphe of the organism, and that if indigo is placed in the liquid it collects and rotates near the central nodule just as described by Professor Smith to prove his theory of the presence of water currents.

It is therefore evident that the motion of diatoms is caused by the impelling force of the bubbles of oxygen evolved, and that the direction of the movement is due to the relatively larger amount of oxygen set free first from the forward and then from the rear half of the organism. This accounts for the hesitancy and irregular movements as well as the motion forward and backward over the same course.

The evolving gas seems to act at times as a propeller to push the organism forward and at other times to exert a pulling action to raise the growth on end. The various movements described are the resultants of varying proportions of both of these active forces.

The fact that a longitudinal groove on the under side of the artificial diatom causes it to become more active, due to the expulsion of the gas along the line of the groove, explains the greater activity of the Raphideæ.

The most interesting and peculiar movements among diatoms are those of *Bacillaria paradoxa* whose frustules slide over each other in a longitudinal direction until they are all but detached and then stop, reverse their motion and slide back again in the opposite direction until they are again almost separated. When the diatoms are active, these alternating movements take place with very considerable regularity. It is probable that the individuals in a group of Bacillaria are joined together much more

loosely than other laterally attached genera and that when a forward movement takes place in the outer individual it is arrested by capillarity just before the diatom is completely detached.

It can now be readily seen that the strange movements of the other microscopic plants may be explained as also due to the evolution of oxygen gas. While the movements of desmids are not as strongly marked as those of diatoms, many of them, notably Penium and Closterium, have often been described as having a power of independent motion, and Stahl[1] found that this motion is greatly affected by light.

The best account of the movements of desmids has been given by Klebs.[2] This author speaks of four kinds of movements in desmids, *viz.*: —

(1) A forward motion on the surface, one end of each cell touching the bottom, while the other end is more or less elevated and oscillates backwards and forwards.

(2) An elevation in a vertical direction from the substratum, the free end making wide circular movements.

(3) A similar motion, followed by an alternate sinking of the free end and elevation of the other end.

(4) An oblique elevation, so that both ends touch the bottom — lateral movements in this position; then an elevation and circular motion of one end, and a sinking again to an oblique or horizontal position.

This observer considered these movements to be due to an exudation of mucilage, and the first two to the formation, during the action, of a filament of mucilage by which the desmid is temporarily attached to the bottom and which gradually lengthens.

These four kinds of movements are very easily explained by the theory of the evolution of gas, and by regulating the conditions they can be exactly reproduced in the artificial desmids made of aluminum. In this case strips of thin aluminum foil should be used. When the gas production is very strong at one

[1] *Verhandl. phys. med. Gesellsch. Würzburg*, 1880, p. 24.
[2] *Biol. Centralblatt*, 1885, p. 353.

end, the desmid will be raised to a vertical position and will take up oscillating or circular movements.

If we now pass to a consideration of like movements in the Cyanophyceæ, the same explanation holds true for Oscillaria which often takes up a waving or circular motion when attached at one end. This movement is well described by Griffith and Henfrey[1] as follows: "The ends of the filaments emerge from their sheaths, the young extremities being apparently devoid of their coat; their ends wave backward and forward, somewhat as the forepart of the bodies of certain caterpillars are waved when they stand on their prolegs with the head reared up." The authors attribute this motion to "irregular contraction of the different parts of the protoplasm."

The free-swimming species of Nostoc all have a spontaneous power of active motion in water, and in all of the filiform orders of the Cyanophyceæ, detached portions of the filament known as hormogones also have the power of spontaneous motion. All of these movements can be exactly duplicated with lithia tablets in water or with aluminum of the proper weight and shape immersed in strong caustic solution, and are also undoubtedly caused by the strong evolution of oxygen gas due to the activity of the chlorophyl present in the organisms.

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[1] *Micrographic Dictionary*, p. 561.

SYNOPSES OF NORTH AMERICAN INVERTEBRATES.

XX. Families and Genera of Araneida.

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The body of a spider is very distinctly divided into two parts: the anterior, or cephalothorax, or carapace, and the posterior, or abdomen. The cephalothorax is supposed to be the equivalent of the head and thorax of insects. Near the middle of the cephalothorax is a dorsal or median groove; from this groove radiate furrows, called radial furrows. The region of the cephalothorax between the anterior pair of furrows is called the pars cephalica, or head; the part behind is known as pars thoracica. The eyes are situated upon the front part of the pars cephalica; the region they occupy is known as the eye-region, eye-area, or ocular area. The eyes are usually eight in number, sometimes six, more rarely two or none. They are arranged in transverse rows, often two, sometimes three or four. References to the eyes are in the form of abbreviations, S. E., meaning side eyes; A. E., anterior eyes; P. E., posterior eyes; M. E., middle eyes; P. M. E., posterior middle eyes; A. S. E.,

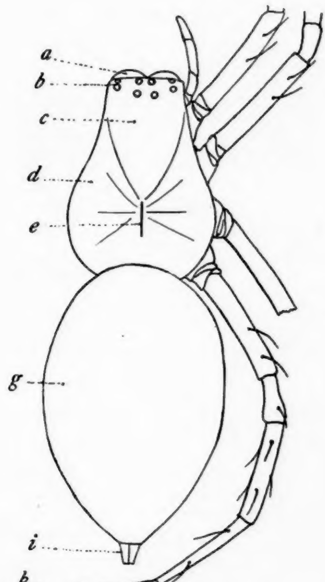

FIG. 1.—*a*, mandible; *b*, eyes; *c*, pars cephalica; *d*, cephalothorax; *e*, dorsal groove; *g*, abdomen; *i*, spinnerets; *k*, claws.

anterior side eyes, etc. Sometimes the most posterior eyes are called the dorsal eyes. An eye-row is either straight or curved. When the S. E. of a row are farther back than the M. E. of that row, the row is said to be recurved; when the S. E. are more forward, the row is procurved. Dark-colored eyes are considered to be diurnal in function, and pale eyes nocturnal. Many spiders have both kinds and the difference in appearance of the two is often very striking. The arrangement of the eyes is of the greatest importance in systematic araneology. The space between the anterior eye-row and the front or clypeal margin of the cephalothorax is called the clypeus, or fillet. Attached just below the clypeal margin are the mandibles, jaws, falces, or cheliceræ, as they are variously termed. Each is of two parts: the basal joint, or larger part, and the fang, or apical part. The fang fits down into a groove of the basal joint, which is often margined with a few small teeth. The poison glands open near the tip of the fang. The mandibles are usually vertical, sometimes uplifted, or porrect. Sometimes they are divergent, and in some cases the basal part is swollen above in front, and the mandible is then said to be geniculate. At the outer base of each basal joint there is, in some families, a small area separated from the rest of the surface; this is styled the boss, or lateral condyle.

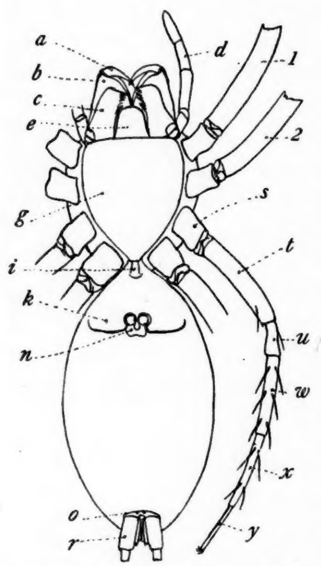

FIG. 2.—*a*, fang; *b*, mandible; *c*, maxilla; *d*, palpus; *e*, lip; *g*, sternum; *i*, pedicel; *k*, epigastric plate; *n*, epigynum; *o*, rima ventralis; *r*, spinnerets; *s*, coxa; *t*, femur; *u*, patella; *w*, tibia; *x*, metatarsus; *y*, tarsus; *1*, leg I; *2*, leg II.

The mouth-parts seen from below are a median piece, the lip or labium, and a piece on each side, the maxillæ, or endites. In some cases the maxillæ show an oblique furrow or impres-

sion. Each maxilla bears a jointed appendage, the palpus. In the female, the palpus is always simple, but in the male, when mature, the last joint is enlarged, concave within, and furnished with a number of more or less corneous and curved pieces, which serve as accessory sexual organs. The shape of these male palpi is of great value in the study of species. The sternum is the ventral plate of the cephalothorax; it is surrounded by the eight legs. In some species there are scars or impressions on the sternum. The legs are numbered from before backward as follows: I, II, III, IV. They are seven-jointed, each joint from the basal outward known as follows: coxa, trochanter, femur, patella, tibia, metatarsus or protarsus, and tarsus; in a few forms there is a small eighth joint, the onychium. At the tip of the tarsus, or onychium if present, are two claws, equal in size; below and between them, in some families is a third claw. Sometimes in place of the third claw there is a dense brush or fascicle of hair. The claws are often toothed or pectinate. In a few groups there are specialized branched hairs at the tip of the tarsus which may act as accessory claws. Sometimes there is a brush of hairs along the lower side of the tarsus or metatarsus; this is called a scopula. Sometimes there is a row of serrate bristles under tarsus IV; this is known as a comb.

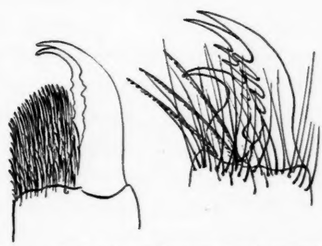

FIG. 3.—Tarsi with two claws and brush, and with three claws.

The abdomen is joined to the cephalothorax by a slender pedicel. At or near the tip of the abdomen on the under or ventral side are the spinning organs, or spinnerets. They are of three pairs, the middle pair smaller and concealed by the other two. Sometimes one pair is very plainly of two joints. At the base of the lower pair there is sometimes a transverse surface provided with (Fig. 4) spinning tubes similar to those of the spinnerets; this is the cribellum. Comple-

FIG. 4.—Cribellum.

mentary to this in function is a row of stiff hairs or bristles on each posterior metatarsus, known as the calamistrum (Fig. 5). The spider possessing these accessory spinning organs can produce a peculiar curled silk by using the calamistrum to comb out the threads from the cribellum. In some cases there is a conical piece between the lower pair of the spinnerets, termed the colulus. In the tarantulas and allied spiders there is a small post-abdomen above the spinnerets. Near the base of the spinnerets is a pair of stigmata or tracheal spiracles; these are sometimes placed more anteriorly, and even as near the base as the tip of the abdomen. When so situated a transverse fold or furrow is formed, known as the ventral furrow, or rima ventralis. Near the base of the abdominal venter is a transverse slit on each side. These are the lung-slits or epigastric furrows, which open into the breathing organs called lung-books. In some spiders there are two pairs of these slits, or there may be a tracheal spiracle behind the first pair. The hardened cuticle over the lung-books forms the epigastric plates. Between the plates on the median line is the opening of the reproductive organs. The genital aperture of the female is termed the epigynum or vulva, and that of the male, small and inconspicuous, is the epiandrium. The epigynum is often of a very complicated nature, and is of much value in the study of species. In some cases there is a pointed piece projecting below the abdomen known as the finger of the epigynum. The furrow behind the epigynum is called the rima genitalis. In some forms there are corneous plates, shields, or scutæ on the abdomen, either above or below. Small circular spots are sometimes called sigillæ.

FIG. 5.— Calamistrum.

The legs and body are clothed with hairs, bristles, scales, or articulated spines. The arrangement of the latter upon the legs is often of great systematic value. If there are two rows of these under tibia I, each row of three spines, then tibia I is said to have spines 3–3. Sometimes these hairs or bristles form tufts, crests, or fringes. On the dorsum of the abdomen there is sometimes a leaf-like mark known as the folium. In some cases there are short, oblique marks in pairs on the dorsum;

these are called chevrons. The legs may have longitudinal marks — stripes; or transverse marks — bands.

Spiders at birth are often very different from their later stages, so that it is impracticable to identify them by tables prepared for adults. However, many spiders when one or two months from maturity are sufficiently similar to their parents to be placed in the proper genus. None but specialists should attempt the specific identification of immature spiders. At maturity the female has her epigynum exposed, and the male has the complicated structures of the palpi uncovered. Spiders without these developments should not be studied by the beginner. There are a few forms of uncertain generic position which have not been included in the tables. They are rare, doubtless more so than various new generic forms that have not yet been collected, though occurring in our country. The spider fauna of many portions of the South and West has been only slightly explored, while a closer examination of our southern borderland will reveal various genera now known to occur in Central America only. Nevertheless the more common spiders in any portion of our country will be found in the following tables

MYGALOMORPHA.

Two pairs of lung-slits on venter of abdomen; fangs of mandibles moving vertically, parallel to each other.

1. Legs very long and slender, femur I longer than body . . . Hypochilidæ.
   Legs short and heavy, femur I shorter than body . . . Theraphosidæ.

ARACHNOMORPHA.

But one pair of lung-slits on venter of abdomen; fangs of mandibles moving somewhat horizontally, toward each other.

1. Without eyes; small pale cave spider (Antrobia) . . . Linyphiidæ.
   With six or eight eyes . . . . 2.
2. With eight eyes . . . . 3.
   With but six eyes . . . . 31.
3. All eyes close together upon a small tubercle or eminence; large species, yellowish brown or brown in color . . . . . Filistatidæ.
   All eyes not situated upon a small median tubercle . . . . 4.
4. Apex of abdomen surrounded by a circle of bent hairs; small species

with flat cephalothorax, maxillæ curved around lip, and the posterior, middle eyes elongate and curved; eyes not in two transverse rows . . . Urocteidæ.

No circle of bent hairs around tip of abdomen . . . . . 5.

5. With a cribellum and calamistrum in female . . . . . 29.

Without cribellum and calamistrum . . . . 6.

6. Eyes always in three or four transverse rows; eyes of next to last row extremely small, the middle eyes of first row (or the first row in Lyssomanes) are very much larger than other eyes; clypeus always vertical, never sloping; cephalothorax never very broad, legs rather short; jumping spiders . . . . Attidæ.

Eyes in two or three rows; when in three rows, then the middle of first row are not greatly larger than any others, and those of second row not greatly smaller than others . . . . 7.

7. Each tarsus with three claws: spinning webs; or else eyes are often in three rows . . . . 14.

Each tarsus with but two claws; never spinning webs; eyes rarely in three rows; S. E. rarely contiguous; never with but two spinnerets 8.

8. Posterior eye-row so much procurved as to represent two rows, the P. M. E. oval; maxillæ long and tapering; fang of mandibles very long; trochanters longer than usual, anterior coxæ much longer than others . . . Prodidomidæ.

Without such combination of characters . . . . . . 9.

9. P. M. E. large, closer to the small A. S. E. than the latter are to the A. M. E., which are also small; tarsi with scopula; cephalothorax not broad and flat, legs rather laterigrade . . . . . . Ctenidæ.

P. M. E. not as close to A. S. E. as latter are to A. M. E., or if so, then eyes nearly equal in size . . . . 10.

10. P. M. E. black; legs I and II laterigrade, that is, articulated so that the anterior surface is directed upward. Second pair of legs nearly always as long as the fourth, or longer, and about as large and long as leg I; spinnerets not prominent; cephalothorax usually broad and abdomen often depressed . . . . 11.

P. M. E. pale, only A. M. E. dark; legs I and II not laterigrade; leg II usually noticeably shorter or smaller than either leg IV or leg I; cephalothorax longer . . . . 13.

11. A. M. E. some distance from clypeal margin, tarsi often not scopulate; spiders of medium size . . . . Thomisidæ.

A. M. E. close to clypeal margin, cephalothorax flatter, tarsi heavily scopulate, mostly large spiders . . . . 12.

12. Tarsal claws pectinate, maxillæ not inclined over lip; very large spiders . . . Sparassidæ.

Tarsal claws smooth, maxillæ inclined over lip; spiders of moderate size . . . Zodariidæ.

13. Lower spinnerets distinctly separated, rather long and prominent;

maxillæ with an obliquely transverse furrow or groove, outer side often concave; abdomen often depressed . . . . . . Drassidæ.

Lower spinnerets contiguous; maxillæ usually without furrow, outer. side convex . . . . Clubionidæ.

14. With but two spinnerets, which are very prominent, but not two-jointed, eyes in two rows, legs short and heavy; maxillæ inclined over lip Zodariidæ.

With six spinnerets . . . . 15.

15. Three eyes on each side in a group, the P. M. E. touching the P. S. E.; cephalothorax rounded and flat, the pars cephalica very small; legs long and without spines, maxillæ surrounding the lip . . Pholcidæ.

P. M. E. never touch P. S. E.; only two eyes in side group, pars cephalica occupying entire front of cephalothorax . . . . 16.

16. Eyes in two rows, more or less curved; no scopula; P. S. E. never much larger than eyes of front row; when P. M. E. are as far apart as A. S. E. (which is rare) then the legs are not spined . . . 17.

Eyes usually in three (or four) rows, when in two rows, then the P. S. E. are much larger than the eyes of front row, or the tarsi are scopulate, or the P. M. E. are farther apart than the A. S. E. (Hamataliva), and the legs spined . . . . 24.

17. Legs I and II long, with rows of two kinds of spines, one long, and the other in between are very short and curved . . Mimetidæ.

No such spine arrangement on legs . . . . 18.

18. Males only: — mandibles concave from in front, and bowed outward in middle; tibia of male palpus with a process on outer side at base Dictynidæ.

Males and females: — former never with such mandibles, and tibia of palpus not often armed at base . . . . 19.

19. Upper spinnerets long and two-jointed; or else with the mandibles geniculate at base, and the A. M. E. only dark; no comb on hind tarsi; legs with spines; making flat irregular webs . . . . . . 20.

Upper spinnerets not long and two-jointed, mandibles not prominently geniculate at base, other eyes besides A. M. E. are dark; S. E. often contiguous . . . . 21.

20. Males only: — A. M. E. scarcely diameter from clypeal margin, upper spinnerets not two-jointed . . . . Dictynidæ.

Males and females: — upper spinnerets two-jointed, or else the A. M. E. are some distance from clypeal margin . . . . . Agalenidæ.

21. A comb on hind tarsus; legs usually without spines; abdomen often globose; maxillæ inclined over lip; clypeus as high as eye-area Theridiidæ.

No such comb; maxillæ usually less inclined over lip; spines often present on legs . . . . 22.

22. Epigynum of female a simple slit; male palpus has a bulb on end of

tarsus terminating in a simple tube; legs rather short, body never high and broad; mandibles not large and porrect . . . Scytodidæ.

Male palpus has the palpal organ quite complicated, and the tarsus partly covers it; the epigynum is more than a slit, else the mandibles are large and porrect, or the abdomen very elongate . . . . 23.

23. At base of mandibles on outer side is a striate or roughened area; clypeus high, higher than height of eye-area; no accessory claws (or serrate bristles) at tip of tarsi; male palpal organ with a tarsal hook; making irregular webs . . . . Linyphiidæ.

At base of mandibles there is no such roughened area, but usually a smooth swelling or boss; clypeus low, usually not as high as height of eye-area; accessory claws (or serrate bristles) at tip of tarsi; making geometric webs . . . . Epeiridæ.

24. Two eyes only in anterior row; clypeus not as high as ocular area 25.

Usually four eyes in front row, if but two, then clypeus is much higher than ocular area . . . . 26.

25. Eyes in four rows, the anterior practically at the clypeal margin, abdomen long and slender . . . . . . Podophthalmidæ.

Eyes not in four rows, the anterior row some distance from clypeal margin; P. M. E. closer to A. S. E. than latter to A. M. E.; body not long and slender . . . . Ctenidæ.

26. Males only: — eyes of second row very much larger than all other eyes together, abdomen long and linear . . . . . Dinopidæ.

Males only: — abdomen not long and linear, eyes not as above; head very low in front; at tips of tarsi are accessory claws as in Epeiridæ, leg I much larger and longer than others . . . . Uloboridæ.

Males and females: — Eyes of second row never so large; abdomen not linear; head rather high or else leg I not larger and longer than leg IV; no accessory claws at tips of tarsi . . . . 27.

27. But two eyes in anterior row, or if four, then median eyes are very small and fully three times their diameter from the side eyes; clypeus very high . . . . Oxyopidæ.

Four eyes in anterior row, middle eyes never so very much smaller nor so far from the side eyes; clypeus much lower . . . . . 28.

28. Eyes in three rows, 4–2–2, those of anterior row very much smaller than others; cephalothorax rather long and narrow, clypeus nearly vertical; no spur at tip of tibia of male palpus . . . Lycosidæ.

Eyes in two curved rows, those of anterior row not so much smaller than others; the cephalothorax broad and flattened; clypeus often sloping; a spur at tip of tibia of male palpus . . . Pisauridæ.

29. Eyes in three rows, 4–2–2, those of second row very much larger than all other eyes together, abdomen very long and linear . Dinopidæ.

No such eye conditions; abdomen shorter . . . . . . 30.

30. S. E. as far apart as M. E.; clypeus low; cephalothorax broad Uloboridæ.

S. E. closer to each other than are the M. E., clypeus high, or if low, then cephalothorax is not unusually broad . . . Dictynidæ.

31. Eyes plainly in three groups of two each; colored species . . 32.
Eyes in two groups of three each, or else all in one group; small, pale species . . . . 33.

32. A pair of stigmata just behind lung-slits; anterior legs large and heavy, never small species . . . . Dysderidæ.
No such stigmata; legs without spines, slender; male palpus at tip of tarsus, lip united to sternum . . . . Scytodidæ.

33. Cephalothorax broad and flat; legs long and slender, none of femora thickened, mandibles small . . . . Pholcidæ.
Cephalothorax more elongate, not flat; mandibles of normal size 34.

34. Legs with spines, and not slender; no cribellum; male palpus partly covered by tarsus, dark species . . . . . . Agalenidæ.
Legs without spines, or else very slender; usually small and pale species 35.

35. Female with cribellum and calamistrum; male has palpal organ partly covered by tarsus; no shields on abdomen, legs without spines Dictynidæ.
Female without cribellum or calamistrum; male has palpal organ at tip of tarsus, wholly exposed . . . . 36.

36. Cephalothorax highest in front of middle; leg I long and stouter than others; three claws to each tarsus . . . . . Leptonetidæ.
Cephalothorax highest behind middle; femora IV thickened at base; two claws to each tarsus . . . . Oönopidæ.

Theraphosidæ.

Palpus arising from the outer basal side of the maxillæ . Atypinæ.
Palpus arising from near or at tip of maxillæ . . . Theraphosinæ.

Atypinæ.

We have but one genus, Atypus, which is rare in the eastern States, with apparently two species. They live in silken tubes which extend some distance above the ground.

Theraphosinæ.

1. Tarsi with a third claw; no tuft or fascicle of hairs at tip . . 2.
Tarsi with but two claws, a fascicle of hairs at tip . . . . 13.

2. Post-abdomen some distance above spinnerets; dorsal groove longitudinal; furrow of mandibles indistinct . . . . . . 11.
Post-abdomen just above spinnerets; dorsal groove transverse or elliptic; furrow of mandibles distinct . . . . 3.

3. Upper spinnerets rather short, last joint short and obtuse; mandibles with a cluster of teeth, or rastellum, in front . . . . . . 5.
Upper spinnerets long, and last joint slender; mandibles without rastellum . . . . 4.
4. Tarsi and metatarsi I partly scopulate; all tarsi unarmed Brachythele.
Tarsi and metatarsi I not scopulate; hind tarsi with spines Evagrus.
5. Tibia III with a deep sulcation above at base . . . . . 6.
No such sulcation . . . . 7.
6. Tip of abdomen broadly truncate, having an almost circular outline Cyclocosmia.
Tip of abdomen normal . . . . . . Pachylomerus.
7. Tarsi I and II not scopulate; with stout spines . Bothriocyrtum.
Tarsi I and II scopulate . . . . 8.
8. Sternal impressions large, close together, and far from margin Myrmeciophila.
Sternal impressions small and near the margin . . . . . 9.
9. Mandibles with four long, equal teeth in front forming the rastellum Actinoxia.
Rastellum of many irregular spines . . . . 10.
10. Tarsus I equal to metatarsus I, latter with only apical spines Amblyocarenum.
Tarsus I shorter than metatarsus I, latter with many spines Aptostichus.
11. With but four spinnerets . . . . . . Brachybothrium.
With six spinnerets . . . . 12.
12. Apical joint of upper spinnerets much longer than preceding; mandibles without a rastellum; no sternal impressions . . . Hexura.
Apical joint of upper spinnerets barely longer than preceding; mandibles with a rastellum; two pairs of small sternal impressions Atypoides.
13. Tibiæ and metatarsi III and IV with very few spines; tarsi shorter and broader . . . . 15.
Tibiæ and metatarsi III and IV with many spines; tarsi longer 14.
14. Metatarsi I scopulate to base, rarely with basal spines Eurypelma.
Metatarsi I not scopulate to base; basal spines present Rhechostica.
15. Eyes of anterior row scarcely unequal, forming a strongly procurved row . . . . Avicularia.
Eyes of anterior row distinctly unequal, forming a nearly straight row Tapinauchenius.

FILISTATIDÆ.

We have but one genus in this country, Filistata, and probably but one species, which is frequent about buildings in the southern States.

UROCTEIDÆ.

We have but one genus in this country, Thalamia Hentz, with two species in the South.

LEPTONETIDÆ.

1. The six eyes in two groups, four in a row in front, and two behind . . . Leptoneta.
   The six eyes in three groups of two each, two in the middle and two each side . . . 2.
2. S. E. form a diverging line, and touch by their sides . . . Usofila.
   S. E. touch at one point, and form a single opening within . . . Ochyrocera.

OÖNOPIDÆ.

Abdomen soft, globose . . . Orchestina.
Abdomen with corneous shield, elongate . . . Gamasomorpha.

SCYTODIDÆ.

1. With eight eyes; body dark . . . Plectreurys.
   With but six eyes . . . 2.
2. Cephalothorax elevated behind, eye-groups widely separate; three claws to each tarsus; palpus of female with a claw at tip . . . Scytodes.
   Cephalothorax not elevated behind; eye-groups more approximate; palpus of female without claw at tip . . . 3.
3. Three claws to each tarsus; anterior eye-row nearly straight; cephalothorax very slender . . . Diguetia.
   Two claws to each tarsus; anterior eye-row recurved; cephalothorax broader . . . Loxosceles.

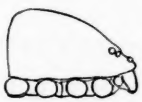

FIG. 6.—Cephalothorax of Scytodes.

PHOLCIDÆ.

1. With six eyes situated rather close together upon a prominent eminence . . . Modisimus.
   Eyes not on an eminence, and in two groups . . . 2.

2. With but six eyes . . . . Spermophora.
With eight eyes . . . . 3.
3. A. M. E. much closer to each other than to A. S. E.; femora very long; abdomen elongate . . . . Pholcus.
A. M. E. as close to A. S. E. as to each other; abdomen globose 4.
4. Femur I not twice the length of cephalothorax, and shorter than femur IV . . . . Pholcophora.
Femur I twice as long as cephalothorax . . . . . . 5.
5. Posterior eye-row slightly procurved; femur I longer than IV Psilochorus.
Posterior eye-row slightly recurved; femur I shorter than IV Physocyclus.

DYSDERIDÆ.

1. Leg III directed backward; spines on sides of tibiæ IV; tarsi scarcely one fourth the length of metatarsi; no spines under metatarsi I Dysdera.
Leg III directed forward; no spines on sides of tibiæ IV; tarsi fully one third the length of metatarsi; spines under metatarsi I . . 2.
2. The M. E. rather closer to A. S. E. than to P. S. E. . . Segestria.
The M. E. closer to P. S. E. than to A. S. E. . . . Ariadne.

PRODIDOMIDÆ.

This is represented in our country by but one genus, Prodidomus Hentz, with one species, found in dark situations in houses in the southern States. An allied genus, Zimiris, occurs in Mexico, and differs from Prodidomus in having the inferior spinnerets very much longer than the others.

ZODARIIDÆ.

With but two distinct spinnerets; cephalothorax rather high; tarsi with 3 claws . . . . Lutica.
With more than two spinnerets; cephalothorax rather flat; tarsi with but two claws . . . . Homalonychus.

DRASSIDÆ.

1. Mandibles with a plate or lobe on under side behind the fang; posterior eye-row plainly recurved . . . . 2.
Mandibles without such plate, only one or two teeth; posterior eye-row often procurved or straight, rarely a little recurved . . . . . 3.
2. Posterior eye-row broader than anterior row; P. S. E. not much larger than P. M. E.; head broad . . . . Gnaphosa.

Posterior eye-row not broader than anterior row; P. S. E. plainly larger than P. M. E.; head narrow . . . . Callilepis.

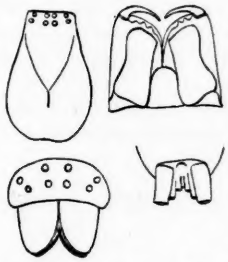

FIG. 7.—Drassidæ; face, cephalothorax, mouthparts, and spinnerets.

3. No dorsal groove; posterior eye-row slightly recurved; cephalothorax reddish yellow . . . . Sergiolus.
   Dorsal groove present, posterior eye-row rarely recurved . . 4.
4. P. M. E. much nearer to P. S. E. than to each other; cephalothorax and abdomen bivittate . . . . Cesonia.
   P. M. E. as near each other as to P. S. E., or at least, abdomen not bivittate . . . . 5.
5. Upper spinnerets plainly two-jointed, and longer than the lower pair; large dark-colored species; tarsi and metatarsi I, II, and III heavily scopulate . . . . Teminius.
   Upper spinnerets not plainly two-jointed and not longer than lower pair . . . . 6.
6. Posterior eye-row slightly recurved; P. M. E. widely separate; no spine above on base of tibiæ III and IV . . . . 7.
   Posterior eye-row straight or procurved . . . . . . 8.
7. Posterior eye-row plainly broader than anterior row; P. S. E. barely, if any, larger than P. M. E.; S. E. more than diameter apart Pœcilochroa.
   Posterior eye-row barely longer than anterior row; P. S. E. much larger than P. M. E.; S. E. not diameter apart; smaller spiders Eilica.
8. Posterior eye-row plainly procurved, P. M. E. oval . . . . 9.
   Posterior eye-row little if at all procurved, and usually barely longer than anterior row . . . . 11.
9. Posterior barely longer than anterior row; P. M. E. approximate and larger than P. S. E. . . . . Megamyrmecion.
   Posterior row plainly longer than anterior row; P. M. E. rather widely separate . . . . 10.
10. Two spines above on tibiæ III and IV . . . . Drassodes.

No spines above on tibiæ III and IV . . . . . . Drassus.

11. P. M. E. large, oval, contiguous or nearly so; no spine above on base of tibiæ III and IV; usually with but one or two spines below tibia I Zelotes.

P. M. E. smaller, nearly round, and plainly separate; a spine above on base of tibiæ III and IV; usually four to six spines below tibia I Herpyllus.

P. M. E. smaller, oval, well separated; no spines above on base of tibiæ III and IV; ten spines below on tibia I . . Drassinella.

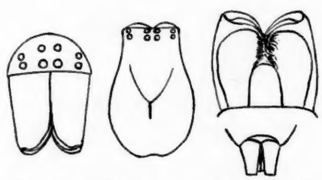

FIG. 8.—Clubionidæ; face, cephalothorax, mouth-parts, and spinnerets.

CLUBIONIDÆ.

1. On the venter there is a transverse furrow, remote from spinnerets, representing the openings of the posterior spiracles . . . . . 10.

No such furrow remote from spinnerets . . . . 2.

2. Two rows of large spines under tibiæ I and II, more than two in each row . . . . 11.

Not more than 2–2 spines under tibiæ I and II, or else irregularly situate, and banded legs . . . . 3.

3. Maxillæ impressed with an oblique furrow, as in the Drassidæ, no dorsal groove . . . . Micaria.

Maxillæ without furrow, convex; dorsal groove usually present . 4.

4. Leg I plainly longer than IV; body and legs pale; spines on legs Chiracanthium.

Leg I not longer than IV . . . . 5.

5. No spines on legs, or only a few under tibia I . . . . . 6.

Spines fairly numerous on legs . . . . 7.

6. Posterior eye-row strongly recurved . . . . . Trachelas.

Posterior eye-row straight . . . . Meriola.

7. A. M. E. several times their diameter from clypeal margin; often a horny spot near base of abdomen; legs usually partly dark Castaniera.

A. M. E. scarcely diameter from clypeal margin, no horny spot on abdomen, legs never dark . . . . 8.

8. Lip longer than wide; mandibles long; cephalothorax not mottled. Clubiona.

Lip broader than long; cephalothorax mottled with brown . . 9.

9. Anterior eye-row procurved . . . . Agrœca.

Anterior eye-row recurved . . . . Hilke.

10. The furrow at or before middle of venter; A. M. E. equal to A. S. E. Anyphæna.

The furrow behind the middle of venter; A. M. E. smaller than A. S. E. Gayenna.

11. Sternum broad, prolonged between hind coxæ; posterior eye-row not recurved, tibia I with five or six pairs of spines below . Phrurolithus.

Sternum not prolonged between hind coxæ which are nearly contiguous . . . . 12.

12. Posterior eye-row slightly procurved; five pairs of spines under tibia I Chemmis.

Posterior eye-row recurved . . . . 13.

13. But 3–3 spines under tibia I; two spines above on tibiæ III and IV Syspira

At least 5–5 spines under tibia I . . . . 14.

14. Eyes subequal in size; anterior eye-row recurved . Liocranoides.

Eyes unequal in size; anterior eye-row not recurved . . . 15.

15. A. M. E. smaller than A. S. E.; posterior row weakly recurved Apostenus.

A. M. E. larger than A. S. E.; posterior eye-row strongly recurved Zora.

Fig. 9.—Venter of Anyphæna.

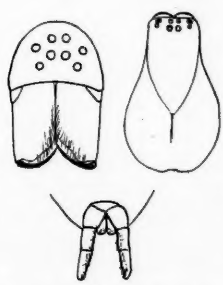

Fig. 10.—Agalenidæ; face, cephalothorax, and spinnerets.

Agalenidæ.

1. Spinnerets arranged in one nearly straight transverse row . Hahnia.

Spinnerets close together, in two rows . . . . . . 2.

2. But six eyes, the A. M. E. lacking . . . . . Chorizomma.

With eight eyes . . . . 3.

3. Both eye-rows very strongly procurved, so much so that the A. M. E. form a nearly straight line with the P. S. E.; cephalothorax narrow in front . . . . Agalena.

Both eye-rows not so strongly procurved . . . . 4.

4. A. M. E. much larger than any other eyes; quadrangle of M. E. as broad below as above . . . . Coras.

A. M. E. not larger than other eyes; quadrangle usually narrower in front . . . . 5.

5. Upper spinnerets of but one joint and not longer than lower pair; posterior eye-row straight or even a little recurved; tarsi I plainly more than one half as long as metatarsus; mandibles geniculate at base Cybæus.

Upper spinnerets of two joints and longer than lower pair . . 6.

6. Basal spine on outer side under tibiæ I and II not reaching to next spine; larger spiders . . . . 7.

Basal spine on outer side under tibiæ I and II reaches to next spine; smaller spiders . . . . 8.

7. Mandibles plainly geniculate at base; legs less slender . . Cœlotes.

Mandibles not or barely geniculate at base; legs very slender Tegenaria.

8. P. M. E. situated fully their diameter apart . . . . . Cicurina.

P. M. E. less than diameter apart, and closer to the S. E. Cryphœca.

FIG. 11.—Spinnerets of Hahnia.

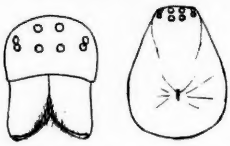

FIG. 12—Theridiidæ; face and cephalothorax.

THERIDIIDÆ.

1. Abdomen with hard skin and furnished with several humps; small species; sternum truncate behind . . . . Ulesanis.

Abdomen without humps and skin soft . . . . . . 2.

2. S. E. widely separate; posterior eye-row recurved . . . . . 3.

S. E. contiguous or nearly so . . . . 4.

3. Leg IV as long as I; abdomen rather flat, and broad behind Epesinus.

Leg I longer than IV; abdomen globose . . . . Lathrodectus.

4. P. M. E. fully four times their diameter apart; abdomen prolonged behind; leg IV about as long as I . . . . . . Spintharus.

P. M. E. rarely over twice diameter apart . . . . . . 3.

5. A. M. E. larger than P. M. E. and much wider apart; clypeus rather high and concave; legs short, IV often as long as I; palpi thick in female . . . . 6.

A. M. E. rarely larger than P. M. E., if so then not wider apart . 7.

6. Abdomen pointed behind and somewhat flat . . . . Euryopis.

Abdomen more globose, broadly rounded behind . . . . Dipœna.

7. Cephalothorax with a transverse furrow in the middle; abdomen usually produced above behind, no chitinous pieces at base; leg I longer than IV . . . . 8.

Cephalothorax with only the ordinary dorsal groove or impression; abdomen not prolonged behind . . . . 9.

8. Abdomen very long and slender, vermiform . . . Ariamnes.

Abdomen much shorter . . . . Argyrodes.

9. On that part of the abdomen that overhangs the cephalothorax there is a chitinous curved piece each side, in the female not prominent, in the male much more so (they form a stridulating organ); colulus present. Leg I usually but little longer than IV; femur I rarely more than one and one fourth length of cephalothorax; leg IV usually longer than II . 10.

No such pieces on base of abdomen, colulus absent; leg I much longer than IV, which is often shorter than II; femur I usually one and one half to twice the length of cephalothorax . . . . . . 17.

10. Sternum broadly truncate between coxæ IV; small species Crustulina.

Sternum pointed behind; coxæ IV closer together . . . . 11.

11. S. E. slightly, but distinctly separate. lower eye-row nearly straight; P. M. E. not large, and rather widely separate . . Lithyphantes.

S. E. contiguous . . . . 12.

12. P. M. E. plainly larger than A. M. E.; abdomen not black, with two yellow spots . . . . 13.

P. M. E. not larger than A. M. E. . . . . 14.

13. Leg IV a little longer than I, all short . . . Pedanostethus.

Leg IV plainly shorter than I, both long and slender . . Teutana.

14. A. M. E. much larger than A. S. E.; leg I longer than IV . Steatoda.

A. M. E. not larger than A. S. E. . . . . 15.

15. Leg IV plainly longer than I; sternum granulate . . Asagena.

Leg I a trifle longer than IV . . . . 16.

16. Femur I not one and one fourth as long as cephalothorax; abdomen rather depressed . . . . Enoplognatha.

Femur I nearly twice as long as cephalothorax; abdomen more slender, and in male, constricted near middle . . . . . Coleosoma.

17. Sternum truncate between hind coxæ; tarsal claws with few or no teeth; leg I not much longer than IV . . . . 18.

Sternum pointed behind; hind coxæ more approximate; tarsal claws pectinate; abdomen usually globose; leg I often much longer than IV 23.

18. No shields or sigillæ on the abdomen . . . . 19.

Shields or sigillæ on abdomen . . . . 21.

19. Abdomen globose; cephalothorax short and high, narrow in front 20.

Abdomen elongate; cephalothorax broad in front; legs banded Ceratinops.[1]

[1] Ceratinops, new genus for *Ceratinella annulipes* Banks.

20. Tibia I not as long as cephalothorax ; cephalothorax very broad ; male eyes elevated . . . . Microdipœna.

Tibia I longer than cephalothorax, which is more elongate than preceding . . . . Mysmena.

21. Abdomen with shield across base . . . . . . Idionella.

Shield not across base . . . . 22.

22. Abdomen of both sexes with dorsal shield ; male with horn from eye-region ; no stiff bristles under femur I . . . . . Histiagonia.

Abdomen of female without dorsal shield, only sigillæ ; male without frontal horn ; a row of stiff bristles under femur I . . Ancylorrhanis.

23. Anterior eye-row procurved ; tibia of male palpus large ; female with abdomen swollen in middle each side . . . . Theridula.

Anterior eye-row straight or recurved ; tibia of male palpus not enlarged ; female not with swollen sides . . . Theridium.

LINYPHIIDÆ.

1. Cave spiders ; no claw at tip of palpus of female . . . . . 2.

Not cave spiders . . . . 4.

2. Without eyes ; sternum broad . . . . Antrobia.

With eyes . . . . 3.

3. P. M. E. about as close to P. S. E. as to each other ; A. M. E. barely diameter apart . . . . Phanetta.

P. M. E. much closer to each other than to P. S. E. ; A. M. E. several diameters apart . . . . Troglohyphantes.

4. No claw to tarsus of female palpus ; epigynum without a finger or hook ; male palpus with a tibial apophysis, usually but one spine above on tibia IV . . . . (Erigoninæ) 16.

A claw to palpus in female ; epigynum with a finger or hook ; male palpus without a tibial apophysis, although sometimes enlarged or a tooth at tip ; usually two spines or erect bristles above on tibia IV (Linyphinæ) 5.

5. Legs without spines ; mandibles long, and their lower anterior border provided with several long, slender teeth ; A. M. E. larger than P. M. E. Tapinopa.

Legs with at least a few spines, or not agreeing with above . 6.

6. Mandibles long, slender, divergent, in front with 3 pairs of long spines, abdomen depressed and rather broad ; P. M. E. less than diameter apart Drapetisca.

Mandibles without the 3 pairs of spines in front . . . . 7.

7. Tibiæ without lateral spines : metatarsus I not longer than tibia I ; usually small spiders . . . . 8.

Tibiæ with lateral spines ; metatarsus I usually as long as, often longer than, tibia I ; larger spiders . . . . 9.

8. Posterior eyes closer together; S. E. on slight tubercles; legs long and very slender . . . . Microneta.
Posterior eyes farther apart; S. E. not on tubercles; legs less slender Tmeticus.
9. P. M. E. plainly closer to P. S. E. than to each other, and larger than S. E.; femora with few if any spines . . . . . . Neriene.
P. M. E. not closer to P. S. E. than to each other . . . 10.
10. No spines on metatarsi; P. M. E. rather close together Bathyphantes.
Spines on metatarsi, at least one . . . . 11.
11. P. M. E. very much larger than S. E., two or three times larger, about one diameter apart, and as far from very small S. E., which are no larger than A. M. E.; abdomen slender . . . . . . Linyphiella.[1]
P. M. E. not much larger than other eyes . . . . . . 12.
12. P. M. E. at least two diameters apart, or else plainly farther from S. E. than from each other; quadrangle of M. E. plainly wider above than below . . . . Linyphia.
P. M. E. scarcely more than diameter apart, and about as close to P. S. E. . . . . 13.
13. All femora with some distinct spines . . . . 14.
All femora not with distinct spines . . . . 15.
14. Tarsus I two thirds of metatarsus I; quadrangle of M. E. rather narrower below . . . . Bolyphantes.
Tarsus I only one half of metatarsus I; quadrangle of M. E. as wide below as above . . . . Labulla.
15. Abdomen high and broad at base, tapering to a point behind Lepthyphantes.
Abdomen elliptical or even broader beyond middle, not tapering behind Frontinella.
16. Tarsus I only about one half as long as metatarsus I, male with lobate head . . . . Hypselistes.
Tarsus I two thirds or more of length of the metatarsus I . . 17.
17.[2] Dorsum of male abdomen with a corneous shield; often present also in female . . . . 18.
Dorsum of abdomen in both sexes without shield . . . . 20.
18. Sternum broadly truncate and slightly concave behind between hind coxæ; usually some corneous pieces on venter; tarsi I but little shorter than metatarsi I . . . . Ceratinella.
Sternum less broad and somewhat convex behind between hind coxæ; no corneous pieces on venter . . . . 19.
19. Tarsi I plainly shorter than metatarsi; no hole in side of male head; P. M. E. but little higher than A. M. E. . . . . . Exechophysis.

[1] Linyphiella, new genus for *Linyphia coccinea* Hentz.

[2] Beyond this the table is based on males, although females will frequently run to proper place.

Tarsi I about as long as metatarsi; a hole in side of head of male; P. M. E. much higher than A. M. E. . . . Lophocarenum.

20. Head of male with a horn from middle of eye-region; sternum rather elongate; posterior eye-row strongly procurved . . Cornicularia.
Head of male without such horn; sternum often broad, triangular 21.

21. Head of male plainly lobed, or at least with a hole in side behind S. E. 22.
Head of male not lobed, nor with a hole in side . . . 26.

22. Metatarsus I of male swollen in middle . . . Caracladus.
Metatarsus I normal . . . . 23.

23. Male with two large and two small tufts of bristles in middle of eye-region; posterior eye-row very strongly procurved . Panamonops.
Male without such tufts; posterior eye-row but little procurved 24.

24. P. M. E. situate upon top of lobe of male . . . . . . 25.
Lobe of male not bearing eyes . . . . . . Dismodicus.

25. Sternum broad, triangular . . . . Diplocephalus.
Sternum more slender . . . . Walckenæra.

26. Male having a horn from middle of clypeus . . Delorrhipis.
Male without such horn . . . . 27.

27. Male palpus with enlarged femur; head of male elevated; posterior eye-row slightly recurved; legs slender . . . . Gonatium.
Male palpus with femur normal . . . . 28.

28. A projection below at tip of tibia of male palpus; sides of cephalothorax often with teeth; posterior eye-row slightly recurved . Erigone.
No such projection to tibia of male palpus . . . . . . 29.

29. S. E. situate on a slight elevation, making head broad in front; sternum rather broadly truncate behind between hind coxæ; tibia I shorter than the cephalothorax . . . . 30.
S. E. not on elevation; sternum narrowly, if at all, produced between hind coxæ . . . . 31.

30. Two rows of spines under metatarsus IV; female with large lateral spines under tibiæ and metatarsi I and II . . . . . Maso.
No rows of spines under metatarsus IV, nor under tibiæ and metatarsi I and II . . . . Ceratinopsis.

31. Tibia I longer than cephalothorax; legs very slender; sternum narrowly truncate between hind coxæ; head of male elevated Notionella.[1]
Tibia I shorter than cephalothorax . . . . 32.

32. Two rows of spines under tibiæ and metatarsi I and II Satilatlas.
No such spines under these joints . . . . 33.

33. P. M. E. closer to each other than to P. S. E.; a hump behind eye-region in male . . . . Grammonota.
Eyes of posterior row about equidistant; no hump behind eye-region . . . . 34.

[1] Notionella, new genus for *Ceratinopsis interpres.*

34. Distance between eyes of posterior row not much greater than diameter of an eye . . . . 35.
Distance between eyes of posterior row more than two diameters of an eye . . . . Acartauchenius.
35. Head of male elevated . . . . Tiso.
Head of male not elevated . . . . . . Gonglydium.

Mimetidæ.

Clypeus lower than ocular area; hind legs much shorter than front legs; lip much longer than broad . . . . Mimetus.

Clypeus as high as ocular area; hind legs not much shorter than front legs; lip but little longer than broad . . . . Ero.

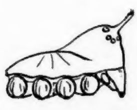

Fig. 13.—Cephalothorax of Cornicularia.

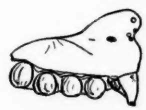

Fig. 14.—Cephalothorax of Diplocephalus.

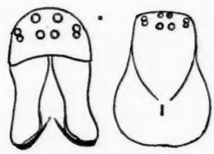

Fig. 15.—Dictynidæ; face and cephalothorax.

Dictynidæ.

1. Legs without spines; cribellum usually undivided in middle by a line . . . . 3.
Legs with spines; cribellum divided by a line; clypeus very low 2.
2. Maxillæ inclined over the lip; hind legs unspined . Titanœca.
Maxillæ straight; hind legs with spines . . . Amaurobius.
3. With but six eyes; colors pale . . . . Neophanes.
With eight eyes, but A. M. E. are sometimes very small . . . 4.
4. Cribellum divided by a line in middle . . . . Dictynina.
Cribellum undivided . . . . 5.
5. A. M. E. very minute . . . . 6.
A. M. E. subequal to others . . . . 7.
6. A. M. E. higher than A. S. E. . . . . Dictyolathys.
A. M. E. between A. S. E. . . . . Prodalia.
7. Lip one third shorter than maxillæ . . . . Lathys.
Lip nearly as long as maxillæ . . . . Dictyna.

Dinopidæ.

We have but one genus, Dinopis, in this country, with one species; a long and slender spider, not common throughout the southern States.

Uloboridæ.

All eyes subequal in size, cephalothorax more elongate . Uloborus.
Eyes of posterior row very much larger than those of anterior row, in fact the A. S. E. are almost invisible . . . . . . Hyptiotes.

Epeiridæ.

1. Mandibles large, strongly divergent, abdomen and legs more or less elongate . . . . Tetragnathinæ.
   Mandibles smaller, not strongly divergent . . . Epeirinæ.

Fig. 16. — Cephalothorax of Tetragnatha.

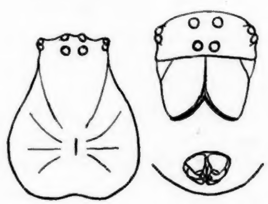

Fig. 17. — Epeiridæ; cephalothorax, face, and spinnerets.

Tetragnathiniæ.

1. Abdomen with a transverse ventral furrow near middle; abdomen not twice as long as broad . . . . Glenognatha.
   Abdomen without such furrow . . . . 2.
2. Abdomen not twice (or barely) as long as broad, not much longer than cephalothorax . . . . Pachygnatha.
   Abdomen three or four times as long as broad . . . . . 3.
3. S. E. as close or closer than M. E. . . . . . Tetragnatha.
   S. E. farther apart than M. E. . . . . 4.
4. Abdomen projecting beyond spinnerets in a tail . . . Eucta.
   Abdomen not projecting beyond spinnerets in a distinct tail Eugnatha.

Epeirinæ.

1. Abdomen with a horny shield, or at least with sigillæ; leg IV longer than I . . . . 2.
   Abdomen without shield or sigillæ; leg IV shorter than I . . 4.
2. Spinnerets enclosed at base by a horny ring; abdomen with spines 3.
   Spinnerets not enclosed by horny ring; abdomen without spines Cercidia.

3. Cephalothorax as broad as long; abdomen broader than long Gasteracantha.
Cephalothorax and abdomen longer than broad . . Acrosoma.
4. Cephalothorax bearing spines or tubercles . . . Ordgarius.
Cephalothorax without spines or tubercles . . . . . 5.
5. Posterior eye-row strongly procurved; metatarsus plus tarsus I plainly longer than tibia plus patella I; cephalothorax rather flat . . . 6.
Posterior eye-row barely, if at all, procurved . . . . . . 7.
6. A. M. E. nearer to each other than to A. S. E., large species Argiope.
A. M. E. as near to A. S. E. as to each other; small species Gea.
7. All metatarsi longer than tibia plus patella; abdomen subcylindric; maxillæ longer than broad; S. E. separate by fully two diameters; legs often with bands of erect hair . . . . Nephila.
Metatarsi shorter than tibia plus patella, rarely equal in fore legs; when so, then maxillæ shorter than broad, S. E. approximate, and no bands of erect hair on legs . . . . 8.
8. Hind femora with a fringe of curved hairs at base; abdomen subcylindric; S. E. approximate; P. M. E. only about twice as far from P. S. E. as from each other; legs very slender and with only a few slender spines Leucauge.
Hind femora without such fringe of erect, curving hairs at base 9.
9. Cephalothorax much elevated behind, sloping forward to eye-region 10.
Cephalothorax not prominently elevated behind . . . . . 11.
10. Legs with long spines; P. M. E. less than diameter apart; no tubercles on abdomen . . . . Mangora.
Legs without spines, or very weak ones; P. M. E. fully two diameters apart; abdomen with tubercles . . . . Carepalxis.
11. Abdomen with a median hump or cone at base, as well as lateral projections; sternum rather long; clypeus high . . . . . Plectana.
Abdomen without median together with lateral projections . . 12.
12. S. E. separated by fully diameter and on separate tubercles . 13.
S. E. contiguous or nearly so, at least upon the same eminence . 14.
13. P. M. E. small and close together; mandibles slender Dolichognatha.
P. M. E. equal to others and widely separate . . . Azilia.
14. P. M. E. scarcely more than one and a half diameter apart, and as close to the P. S. E. as to each other; S. E. slightly separate; all eyes subequal in size; epigynum without a finger . . . . . . 15.
P. M. E. much closer to each other than to P. S. E. . . . . 18.
15. Tarsus IV with many serrated bristles beneath; small spider with globose abdomen . . . . Theridiosoma.
Tarsus IV without serrate bristles beneath; larger species; abdomen not globose . . . . 16.

16. Maxillæ twice as long as broad; mandibles long and slender; abdomen convex above . . . . Meta.
Maxillæ not twice as long as broad . . . . 17.
17. Abdomen elliptical, rather depressed, without humps at base Zilla.
Abdomen subcylindric, with two small humps at base . . Hentzia.
18. No spines above on tibiæ I and II . . . . 19.
With some spines, at least one, above on tibiæ I and II . . 20.
19. Abdomen with spines or humps; cephalothorax broad and tumid in front . . . . Wagneriana.
Abdomen without spines or humps . . . . . Metazygia.
20. Legs very slender, especially leg I, almost destitute of spines; cephalothorax very slender; posterior eye-row strongly recurved Acacesia.
Legs less slender and with a number of distinct spines, or else the posterior eye-row not strongly recurved . . . . 21.
21. Abdomen pointed at base, elongate, sternum one and one half longer than broad; P. M. E. scarcely diameter apart . . . Larinia.
Abdomen not pointed in middle at base . . . . . . 22.
22. Abdomen as high behind middle as at base, and elliptical in outline or broader behind middle; P. M. E. about diameter apart; epigynum without finger; small species, with short legs . . . . . Singa.
Abdomen highest toward base, and usually broadest near base . 23.
23. Cephalothorax with a broad transverse furrow (at least in female); abdomen usually prolonged above behind; A. S. E. never twice as far from A. M. E. as latter from each other; quadrangle of M. E. plainly wider below than above; legs more hairy . . . . . Cyclosa.
Cephalothorax without such furrow; abdomen rarely prolonged above behind; legs more spiny . . . . Epeira.

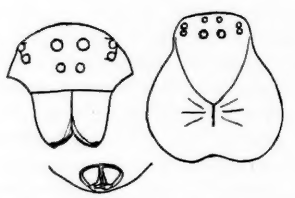

FIG. 18.—Thomisidæ; face, cephalothorax, and spinnerets.

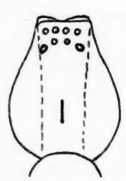

FIG. 19.—Cephalothorax of Pisaurina.

THOMISIDÆ.

1. Legs III and IV not or scarcely shorter than legs I and II; tarsi I and II scopulate (at least in females); hairs of body usually branched, prone not erect . . . . (Philodrominæ) 2.

Legs III and IV much smaller than I and II; tarsi I and II not scopulate; hairs of body, simple, scattered, and erect. (Misumeninæ) 7.

2. Leg II very much longer than I; posterior eye-row almost straight; cephalothorax broad . . . . Ebo.

Leg II but little longer than I; posterior eye-row very plainly recurved 3.

3. Five pairs of spines under tibiæ I and II; P. M. E. nearer to P. S. E. than to each other . . . . Philodromoides.

Less than 5–5 spines under tibiæ I and II . . . . . . 4.

4. P. M. E. farther apart than from P. S. E.; abdomen not very slender; leg IV shorter than leg I . . . . Philodromus.

P. M. E. not nearer P. S. E. than to each other, or if barely so then leg IV is longer than I . . . . 5.

5. P. M. E. much nearer to each other than to P. S. E.; abdomen long and slender; leg IV longer than I . . . . Tibellus.

P. M. E. about as near P. S. E. as to each other . . . . 6.

6. Leg IV shorter than leg I . . . . Apollophanes.

Leg IV longer than leg I . . . . Thanatus.

7. Legs I and II with spines only under tibiæ and metatarsi, at most with one or two very minute ones elsewhere . . . . 8.

Legs I and II with distinct spines elsewhere . . . . . . 10.

8. Abdomen furnished behind with two prominent conical projections Thomisus.

Abdomen without two projections behind . . . . . . 9.

9. A ridge between eye-rows . . . . Runcinia.

No ridge between eye-rows . . . . Misumena.

10. Abdomen high and pointed behind; clypeus sloping; tubercle at P. S. E. much larger than at A. S. E. . . . . Tmarus.

Abdomen broadly rounded behind; clypeus more vertical; tubercles of S. E. subequal in size . . . . 11.

11. Cephalothorax very flat; dark colored species . . . Coriarachne.

Cephalothorax moderately high . . . . 12.

12. Abdomen, cephalothorax, and legs pale whitish or yellowish, but little marked except bands on legs of males . . . . . Misumessus.

Abdomen, or cephalothorax and legs, dark, or heavily marked with dark . . . . 13.

13. Quadrangle of M. E. higher than broad; tibiæ I and II with 2–2 spines . . . . Ozyptila.

Quadrangle of M. E. not higher than broad . . . . . 14.

14. Eyes of lower row equidistant; A. M. E. larger than P. M. E.; tibiæ I and II with 3–3 spines . . . . Synæma.

A. M. E. nearer to A. S. E. than to each other, and not larger than P. M. E.; tibiæ I and II with 4–4 or 5–5 spines . . . . Xysticus.

SPARASSIDÆ.

1. P. S. E. in a row with anterior eyes; tarsal claws smooth; cephalothorax extremely flat . . . . Selenops.
   P. S. E. behind anterior row; tarsal claws toothed; cephalothorax plainly arched . . . . 2.
2. P. S. E. much larger than P. M. E. . . . . . Heteropoda.
   P. S. E. barely, if at all, larger than P. M. E. . . . . Olios.

PISAURIDÆ.

Anterior eye-row recurved; quadrangle of M. E. broader behind than high; clypeus about as high as quadrangle of M. E. . Dolomedes.

Anterior eye-row straight; quadrangle of M. E. not broader behind than high; clypeus not as high as quadrangle of M. E. . . Pisaurina.

PODOPHTHALMIDÆ.

Area outlined by four anterior eyes is much wider than long Thanatidius.

Area outlined by four anterior eyes is as long as wide Maypacius.

CTENIDÆ.

A. S. E. nearer to A. M. E. than to either P. S. E. or P. M. E. Titiotus.

A. S. E. nearer to P. M. E. or to P. S. E. than to A. M. E. Ctenus.[1]

LYCOSIDÆ.

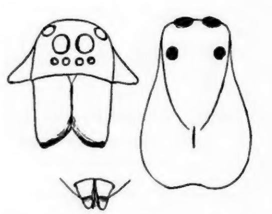

FIG. 20.— Lycosidæ; face, cephalothorax, and spinnerets.

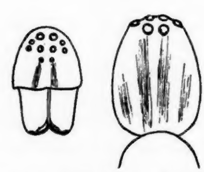

FIG. 21. — Oxyopidæ; face and cephalothorax.

[1] This includes Cupiennius and Anahita; they differ from Ctenus only by minute or slight characters difficult of verification. Titiotus is unknown to me.

1. Tibiæ III and IV with a stout spine at base above . . . . 4.
Tibiæ III and IV without spine at base above, although there may be one near middle above . . . . 2.
2. No spines above on tibiæ III and IV; long hair above on these joints, head large and high . . . . Geolycosa.
A spine near middle above on tibiæ III and IV . . . 3.
3. Upper spinnerets not longer than lower; anterior eye-row not wider than the second . . . . Trochosa.
Upper spinnerets longer than lower; anterior eye-row wider than second row; tarsi heavily scopulate . . . . Sosippus.
4. Cephalic region with a wedge-shaped mark, containing a central stripe; posterior spinnerets longer than others; eyes of second row scarcely their diameter apart, small species . . . . Pirata.
No such mark on cephalic region; spinnerets subequal in length 5.
5. Tibia I with 4–4 imbricated spines, the basal ones reaching beyond base of second ones beyond; very small species; eyes of second row not their diameter apart . . . . Trabea.
Basal spines on tibia I not reaching beyond base of the third pair, usually but 3–3 spines below . . . . 6.
6. Cephalothorax without median mark of any kind; spines under tibia I very short, 3–3 . . . . Allocosa.
Cephalothorax with a paler median stripe or mark . . . . 7.
7. Head with sloping sides, eyes of second row usually scarcely diameter apart; usually 3–3 short spines under tibia I, the basal pair rarely reaching next pair; lip longer than broad; larger spiders . Lycosa.
Head with more vertical sides; eyes of second row more than diameter apart; 3–3 long spines under tibia I, the basal pair usually reaching next pair; lip not longer than broad; smaller spiders . . Pardosa.

Oxyopidæ.

1. Posterior eye-row only slightly procurved; mandibles higher than height of cephalothorax in front; large greenish spiders . Peucetia.
Posterior eye-row strongly procurved; mandibles scarcely as long as height of cephalothorax in front . . . . 2.
2. P. M. E. much closer to P. S. E. than to each other . Hamataliva.
P. M. E. about as close to each other as to P. S. E. . Oxyopes.

Attidæ.

1. Abdomen more or less constricted; cephalothorax usually constricted; pedicel distinctly chitinized . . . . 2.
Neither cephalothorax nor abdomen constricted; pedicel soft . 4.

2. Leg I plainly thicker than the other legs; cephalothorax only slightly constricted . . . . Peckhamia.
   Leg I as slender as others . . . . 3.

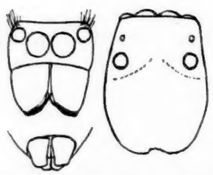

FIG. 22.—Attidæ; face, cephalothorax, and spinnerets.

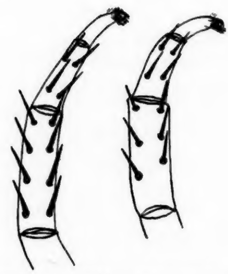

FIG. 23.—Attidæ; two types of spine-arrangement under tibia I.

3. Cephalothorax and abdomen very strongly constricted; apical joints of female palpus slender . . . . Synemosyna.
   Cephalothorax and abdomen but little constricted; apical joints of female palpus enlarged . . . . Myrmarachne.
4. Eyes in four rows; pale green spiders . . . Lyssomanes.
   Eyes in three rows . . . . 5.
5. No spines under tibia I, or at most with one or two small ones 6.
   Several spines under tibia I . . . . 9.
6. Cephalic part very long, reaching almost to base of abdomen; leg I plainly thickened . . . . Homalattus.
   Cephalothorax slopes from before middle to base . . . 7.
7. Leg I plainly heavier than others . . . . 8.
   Leg I slender, as the others . . . . Salticus.[1]
8. No spines on hind legs . . . . Admestina.
   A few distinct spines on hind legs . . . . . . Eremattus.
9. Leg III as long as or longer than IV, at least in males; usually spines on sides of patellæ III and IV; coxæ I separate by more than width of lip; 2–2 or 3–3 spines under tibia I; legs usually quite hairy . 30.
   Leg III plainly shorter than IV . . . . 10.
10. Ocular area occupying fully one half of the cephalothorax, the dorsal eyes situated at its greatest width, and projecting laterally Zygoballus.
   Ocular area occupying less than one half of the cephalothorax; or if so, then the cephalothorax is not plainly broader at dorsal eyes than elsewhere . . . . 11.
11. Tibia I with 4–4 spines below (or less), the basal one of inner series is nearer to base than the first third of tibial length . . . . . 12.

[1] Latreille in 1810 fixed type of this genus as *S. scenicus*.

Tibia I with 3–3 spines (or less), the basal one of inner series situate one third of tibial length (or greater distance) from base; coxæ I usually widely separate . . . . 22.

12. Metatarsus IV heavily spined near base and middle, both below and on sides; cephalothorax never very low, nor very broad; usually spines on patellæ III and IV . . . . 17.

Metatarsus IV spined only at tip, or with one or two weak spines on sides; never a basal and middle circle of spines . . . 13.

13. Coxæ I approximate; leg I plainly thickened; sternum usually long; usually large species . . . . 15.

Coxæ I widely separate; leg I barely thickened; sternum short; very small species, with a narrower cephalothorax . . . . . 14.

14. Ocular area occupying nearly one half of cephalothorax; as wide in front as behind, dorsal eyes as large as laterals of first row; no spines below on tarsus IV . . . . Neon.

Ocular area less than one half of cephalothorax, rather wider behind; dorsal eyes smaller than laterals of first row; spines below on tarsus IV Attidops.

15. Abdomen about four times as long as broad; tibia I with 4–4 spines below . . . . Hyctia.

Abdomen much shorter . . . . 16.

16. Eye-region occupying two fifths of cephalothorax; the sternum nearly as broad as long, smaller species . . . . . . Fuentes.

Eye-region occupies about one third of cephalothorax; the sternum much longer than broad; larger species . . . . . Marpissa.

17. Tibia I with 4–4 spines below . . . . 18.

Tibia I with less than 4–4 spines below . . . . . . 19.

18. Ocular area slightly narrower behind than in front; leg IV plainly longer than I . . . . Mævia.

Ocular area barely narrower behind, leg I as long as IV Plexippus.

19. Cephalothorax rather long; eye-area occupying scarcely one third of length; tibia I with 3–3 spines . . . . 20.

Cephalothorax shorter; eye-area occupying fully two fifths of length; coxæ I widely separate . . . . 21.

20. Basal spine of femora III and IV about one half as long as the joint; abdomen vittate . . . . Phlegra.

Basal spine of femora III and IV much shorter; abdomen not vittate Sidusa.

21. Patella III as long as IV, no patellar spines . . . Euophrys.

Patella III shorter than IV, patellar spines present . . . Attus.

22. Cephalic part about two thirds of cephalothorax, reaching almost to abdomen; legs short, leg I thickened; hind metatarsi spined only at tip Homalattus.

[1] Attidops, a new genus for *Ballus youngi* Peck.

Cephalic part far shorter . . . . 23.

23. Cephalothorax high, and rather broad; quadrangle of eyes wider behind than in front; large species, rarely under 7 mm.; leg I heavy and very hairy, often with fringes of hair, mandibles often iridescent; often a group of stout bristles near lateral eyes . . . . Phidippus.

Cephalothorax not as high and heavy, leg I not so hairy; smaller species, rarely over 6 mm. . . . . 24.

24. A spine above before middle on tibia III and IV, and above on base of metatarsus IV; leg I not thickened; small species . . Attinella.[1]

No spines above on tibia III and IV, nor on base of metatarsus IV 25.

25. Tibia I with 2–2 large spines, and toward base are two pairs of large bristles with enlarged bases, not obscured by other hairs; metatarsi IV spined throughout, patellæ III and IV with spines; leg I not much thickened . . . . Thiodina.

Tibia I without such bristles, distinct from all else, 3–3 spines below 26.

26. Legs with few hairs (except sometimes a brush under tibia I in male), tibia I about three times as long as broad, with very small spines; legs lineate with dark . . . . Tutelina.

Legs more hairy, tibia I much stouter; legs not lineate (or rarely) with dark . . . . 27.

27. Cephalothorax much broader than width of dorsal eye-line; tibia and metatarsus I in male elongate; abdomen quite slender; leg I not very heavy; legs III and IV not plainly banded . . . . Wala.

Cephalothorax narrower at dorsal eyes; tibia and metatarsus I not elongate in male . . . . 28.

28. Cephalothorax plainly depressed; leg I very much thickened, male with horny shield on base of abdomen . . . . . Metacyrba.

Cephalothorax higher; male without shield at base . . . 29.

29. Tibia I plainly convex below; legs less hairy; cephalothorax longer Icius.

Tibia I barely convex below; legs more hairy; cephalothorax shorter Dendryphantes.

30. Very few spines on hind legs, none above on bases of tibiæ III or IV, nor on base above of metatarsus III; quadrangle of eyes wider in front; smaller, less hairy species . . . . Habrocestum.

Hind legs with many spines, often one above on base of either tibia III or IV or both, and a spine above on metatarsus III; quadrangle of eyes usually wider behind . . . . Pellenes.

[1] Attinella, a new genus for *Attus dorsatus* Banks.

[2] Includes Evarcha Simon; our one species (which seems to be the same as the *E. paleata* of Europe) cannot be readily separated by generic characters from some Pellenes.

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BIOLOGY OF *ACMÆA TESTUDINALIS* MÜLLER.

M. A. WILLCOX.

Acmæa testudinalis Müller, the tortoise-shell limpet, as it is called by Forbes and Hanley, is the common limpet of our New England shores. It, together with its variety *alveus*, is the sole representative on this coast not only of its genus and family but of the entire group of the Docoglossa and by far the most convenient example of the suborder Diotocardia, which includes all the more primitive Gasteropods. It is abundant and accessible, it is easily kept alive in aquaria, and living as it often does in tide-pools, is conveniently observed under its natural conditions. But in spite of these facts it has never been made the subject of careful study.

I am at present engaged upon a paper which is intended to supply this lack and from which I excerpt the following biological notes.

Acmæa is a large genus whose eighty-four species are widely scattered over both northern and southern hemispheres. Representatives have been recorded not only from both eastern and western shores of all the great continents except Africa,[1] but from Australia, from New Zealand, and from many islands of the Atlantic and Pacific including some which are oceanic. The genus is at present arranged only tentatively. "More than any other shells, these must be studied with constant reference to not only habitat geographically, but *station* as well. For an exact knowledge of the group we must therefore wait until observations on the species are made with special reference to their modes of life and surroundings" (Pilsbry). It seems probable, moreover, that a careful comparative study of the different species might throw light upon various questions of geographical distribution. This statement of the final aim of

[1] Two species only are as yet recorded from this continent: one from Natal and one from Cape Town.

the investigation may serve to explain the presence in these notes of material that might otherwise seem trivial. It is believed that nothing has been admitted which does not bear on the general question.

Limpets are found on the entire New England coast and northward to the Arctic Ocean. Comparatively rare and local south of Cape Cod, they increase in numbers and in size as one passes northward until at Eastport, Maine, they are one of the most abundant of the littoral molluscs. They are found between tide-marks in pools and also in such shaded places as provide them at once with coolness and moisture. The vertical face of a rock heavily hung with dripping Fucus or the under surface of the larger beach pebbles are attractive spots. Although they are to be found occasionally where the water is at least slightly fouled by sewage, as in the estuary at Beverly, they are far more abundant in that which is clean and pure.

So far as reported they seem to reach their maximum size in the region of Eastport, which is bathed by the cool waters of the Arctic current. On the Massachusetts coast a limpet an inch long is a giant but at Eastport they not rarely reach a length of 32 mm. The first explanation of this fact which presents itself is of course that the cooler water presents the optimum temperature for these animals; this is not, however, the only possible explanation. The Arctic current is not only cooler but more equable in temperature than more southern waters. At Eastport the maximum yearly variation in temperature of the water is about 12° C. (32.5°–54° F.): at Boston it is nearly 23° C. (29°–70° F.).[1] Limpets living entirely below tide-mark would therefore enjoy comparatively equable temperature conditions at Eastport. This would not, however, be true for those living between tide-marks, for the annual variation in temperature of the air at Eastport is often as much as 35° C. (4°–67° F.) — 10° C., it may be, in a single month. Bathed twice a day by the water, exposed twice a day to the air, such individuals in spite of the comparatively cool places which they affect, would be exposed to condi-

[1] These figures are deduced from the records of the U. S. Weather Bureau at Eastport and Boston, for the years 1887–89, the only years during which observations of water temperature were made.

tions probably at least as variable as those of the Massachusetts waters. If now we examine their size with reference to their habitat, we find that the limpets of Eastport are large only when living at or near the low-water mark of spring tides so that they are rarely or never left uncovered by the sea, and that higher up on the beach the animals though no less abundant are of smaller size, no larger in fact than with us. We find also that in Massachusetts there is no marked difference in size between limpets which are continuously submerged and those which live between tide-marks. The conclusion is therefore forced upon us that size in these animals is correlated not necessarily with a low but with an equable temperature. The advantage of uniform thermal conditions was long ago pointed out by Möbius and Semper.

In the late autumn, limpets in the neighborhood of Boston either altogether disappear or become very scarce, reappearing in numbers in March or April. In Eastport, however, they remain near the shore for the entire year. Their disappearance from the Massachusetts coast is probably due to a retirement to deeper water; this is, I am told by Professor S. I. Smith, the practice among several of our littoral animals. Limpets will stand a good deal of cold; Miss Annie Sullivan, an observant and intelligent collector who is familiar with the animals at Eastport, tells me that she has revived them after ice had formed within the shell and found them apparently no worse for the experience. It seems very probable therefore, that when they withdraw in the autumn they go only a little below tide-mark, thus avoiding the very considerable daily variation in temperature to which they would often be subjected if they remained above the low-water line.

The distribution of limpets as given above is taken from Smith and Verrill's "Invertebrate Animals of Vineyard Sound," a work which was published nearly thirty-five years ago. I am not aware that any investigations have been undertaken since that time which would show whether it is still correct. Forbes and Hanley described this species in 1853 as having, at least in Great Britain and Ireland, a tendency to migrate southward and Forbes had already described its sudden appearance nearly

twenty years before on the northern shore of the Isle of Man, where it is still to be found. In view of these facts it would be very interesting to learn whether it is moving southward on our own coast.

Distribution of the adult animal is probably effected not only through its own locomotion but also by the aid of tides and currents. On one occasion, though only on one, I found a limpet crawling back downward on the surface film like a fresh-water snail but I have not very infrequently found them clinging to floating pieces of the larger Floridiæ, upon which they feed. It will be remembered that Nacella and Helcioniscus live habitually upon the large fronds of Macrocystis. Occasional transportation of the adult by such means may not impossibly be a more effective factor in its distribution than the brief pelagic life of the young, which Boutan found in the case of *A. virginia* to be limited, at least in the waters of Roscoff, to a few days' duration.

Locomotion is almost exclusively effected by crawling over the substratum. Progress is exceedingly slow; the fastest crawling of which I have record was at the rate of about three inches per minute. This was in a tide pool where the animal was undisturbed and in natural conditions. Under such circumstances it often remains motionless for hours. In captivity it is not unusual to find one limpet crawling over another or adhering to its shell, although in such circumstances I have never observed either individual showing any recognition of the presence of another of its own kind.

In view of the well known homing habits of Patella and of the fact that I have found the same power possessed at least in a limited degree by animals so widely separated as *Fissurella barbadensis* Gmelin and *Siphonaria alternata* Say, I have made repeated attempts to satisfy myself of its existence in Acmæa. These attempts have, however, been unsuccessful. The difficulty lies in the character of the rocks of the New England coast, which are unsuited either to the formation of a sunken "scar" like that which indicates the home of Patella or of a discolored spot like that produced by Siphonaria. It is therefore impossible to locate with certainty the "home" of a limpet, which

is the first step in determining whether or not it possesses the homing power. Dr. W. H. Dall, however, tells me that he has observed on the Pacific coast individuals of *Acmæa spectrum* Reese whose shell margins exactly corresponded to the irregularities of the soft rocks on which they live. Fisher notes that both this and other species of Acmæa are often found adhering to the shells of Lottia in which they have made shallow depressions. These observations furnish the strongest presumptive evidence that in some species, at all events, the homing power is present and render desirable the investigation of the question in *Acmæa testudinalis* under conditions more favorable than those afforded by the New England coast.

The food of limpets appears to be exclusively vegetable. A freshly taken specimen always has the digestive tract stuffed with a finely divided mass of unrecognizable material mingled with which are unicellular algæ and bits of the cortical cells of some of the larger ones. I have made no attempt to identify these organisms. Intermixed with this material are great numbers of tiny stones which probably, like those found in a bird's gizzard, aid in the comminution of the food. This is especially necessary in the limpet since for the greater part of their extent the walls of the alimentary tract are entirely devoid of muscles. These bits of stone are very likely, at least in large measure, fragments rasped off by the radula from the rocks together with the small algæ which cling to them. It has been suggested in regard to Patella that the bits of alga cortex are in like fashion detached, so to speak, by accident together with minute organisms both animal and vegetable, which live upon the alga and which constitute the real food of the limpet. Touching this suggestion I can only say that I have never found in any part of the alimentary tract of *Acmæa testudinalis* remains which could be interpreted as animal in nature and that I have found the animal apparently feeding upon large algæ which so far as one could see, were absolutely free from smaller organisms.

As to habits of feeding I have never been able to observe the act, but twice have, as I believe, interrupted it. In each case the seaweed to which the animal was attached bore a mark, due to the removal of the cortex, which served as a record of the

movements of the snout during feeding. The head is evidently swept slowly from side to side while the animal *backs* gradually along the surface on which it is feeding, removing the food as it goes from a band whose width is equal to the diameter of its own mouth and whose length, disposed in a series of nearly parallel but connected arcs, is proportionate to the length of the feeding time. Removal of the tissue is effected by a licking motion of the odontophore or "tongue" with its superimposed radula but I have not been able to detect any independent motion of the radula although I have made an especial search for a "chain-saw movement" such as Huxley described in certain Heteropods, and Geddes claims to have seen "in live limpets turned over on their backs," and although there are in *Acmæa fragilis* muscles which seem adapted for the production of such a motion. I have also been unable to gather any evidence as to the way in which the individual teeth of the radula are used. Pilsbry has suggested that in Rhipidoglossa the rounded form of the subradular cartilage probably determines a greater activity of the median part of the radula and that this in turn accounts for the greater specialization of the teeth in that region.

Respiration is in general aquatic and the mantle no less than the gill serves as a respiratory organ, as is demonstrated by the disposition of the blood vessels and the course of the flow. Water passes in and out beneath the slightly raised shell and its character may very possibly be tested as among some Pelecypods by the minute tentacles which fringe the mantle. The shell is usually thus raised so long as the limpet is undisturbed though the slightest disturbance causes it to be tightly pressed against the supporting rock.

Atmospheric air may, however, under certain circumstances be respired. When the water in the aquarium has become unduly warm or otherwise deprived of a part of its air, it is a common sight to see the limpets about its edges with their bodies half out of the water, the shell raised to the highest point, and the head stretched forward so that the nuchal cavity may be as widely as possible opened to the air. Such a position seems explicable only on the theory that the animals are seeking to supplement the imperfect gaseous exchange permitted by the water by a true aërial respiration.

Limpets give evidence of the possession of only three special senses: sight, touch, and the temperature sense. If they are placed in water warmer than that to which they are accustomed, they betray their uneasiness by restless wandering about. Visual sensations appear to be limited to the perception of light and darkness. That light is objectionable only when associated with heat seems indicated by the following experiment: a limpet with the pebble to which it was affixed was removed from the shaded to the sunny part of a tide pool. The water, being 12 to 15 inches deep, effectually protected it from the heat of the sun and it showed no desire to move. When the pebble was placed, however, in water only an inch or two deep and so considerably warmer, the limpet exhibited lively discomfort and crawled at once toward the shade. I have assumed that the light-perceiving organs are the eyes but have taken no steps to prove it.

The sense of touch is possessed by the entire body surface though especially localized in the tentacles, both marginal and cephalic, which are richly provided with tactile (Flemming's) cells. The gill also, although without such cells, has an exquisite sensitiveness and from its exploratory movements while the animal is traveling, would seem to serve as an additional organ of touch.

Though the sexes in *Acmæa testudinalis* are distinct, the shells show no sexual differentiation, whether in size or in form; in the ripe animal, however, the sex can usually be determined by a difference in the tint in that part of the foot which immediately underlies the generative gland. The eggs when nearly ripe assume a tint much like that known among dry-goods merchants as "crushed strawberry," and the testis at the same period is of a golden brown. On the left side of the body the gland immediately overlies the foot and is perceptible through its tissue as a patch of dull reddish or of creamy brown bounded in the median plane by a sharp line corresponding to the plane where it abuts against the green nephridium.

The breeding season appears to be a long one; I have taken ripe limpets near Boston as early as the thirteenth of April and as late as the end of July. In Eastport they were still laying

during the first week in September. In each place the generative season probably ends a little before the water reaches its maximum heat, which occurs at Eastport in September, at Boston in August. Thus all of a lot of specimens from Nahant in the middle of August had the generative glands empty and the same was true of a considerable part of those gathered at Eastport during the first few days of September. The eggs, which are about $\frac{1}{5}$ mm. in diameter are not dropped separately, as is said to be the case in Patella, but are imbedded in a layer of very thin mucus in which they lie one layer deep and at regular distances apart. The mucus is secreted not by a special gland but by the sole of the foot.

Fertilization is usually described as external. The only exception that I have been able to find to this statement is that of Fischer, who in 1863, asserted that he had found the ovaries of Patella filled with embryos already provided with the shell. Dr. Dall kindly informs me that he was following this authority when in 1879 he stated that the fertilization in Docoglossa is internal. His statement in turn seems to have been the authority for that made by Tryon in his Manual. While I am not prepared to assert that fertilization is internal I wish to record the following observation, which certainly points in that direction. About nightfall a male was observed caressing a female. Both shells were raised, that of the male overlapping the female and the heads were placed side by side, the male stroking the female with his tentacles. After a few passes he would turn as if he were going to leave her and then come back. The proceeding lasted for about half an hour, the female remaining quiescent with tentacles folded about her head. At the end of this time she moved forward, pressed the left side of the neck against the corresponding region in the male so that the openings of the two nuchal cavities were brought close together, and after remaining a moment or two in this position turned and walked away pushing with some difficulty between two other limpets neither of which paid her any other attention than a momentary touching with the tentacles. The nephridial papilla through which the generative products are extruded lies not on the left but on the right side of the nuchal cavity, but the ciliary current

is outward on that side and inward on the left so that the position which I have described would seem on the whole better fitted than the reverse one for fertilization. On the other hand, however, it should be said that when the animals were killed twenty-four hours later, the ova of the female were unfertilized and no spermatozoa were observed in her nuchal cavity or nephridium. It should also be said that in two instances unfertilized eggs have been laid in my aquaria, but as the same thing sometimes occurs with moths when pairing is prevented, no deduction can be drawn from this fact.

The eggs, at least in the aquaria, are laid about nightfall and the trochosphere is developed in the course of the next day. I have made no attempt to watch the development. Growth must be rapid, as one finds at Nahant in September and early October large numbers obviously of the season's young, which are four or five mm. in length. Sexual maturity is probably acquired after the first winter, as I have taken ripe limpets in April which were under a cm. in length.

The only enemy of the limpet of which I have had any experience is the purple, *Purpura lapillus*. I have found occasional shells bored by this mollusc and in one instance was able to surprise it in the act.

HABITS OF WEST INDIAN WHITEBAIT.

AUSTIN H. CLARK.

THE "tri-tri" or West Indian whitebait (*Sicydium plumieri*), although of small size, is one of the important food fishes of these islands. It is an inhabitant of the mountain streams, and occurs in the quiet pools and eddies formed by the back-water from rapids, from the lowlands well up into the highlands. Its range is about the same on St. Vincent as that of the "trout" (*Agonostomus monticola*), and, like that fish, it is absent from certain of the rivers.

The tri-tri reminds one strongly of the common darter (*Boleosoma nigrum olmsteadi*) in habits. They are usually observed lying motionless on the sandy bottom of pools, head up stream. They will lie in one position for a long while, then, with a sudden jerk, move to another place. If disturbed they dart quickly under the overhanging banks, or under rocks or logs in the stream. When seen on sandy bottom, the color of these fishes is a very light brownish gray, with seven or eight transverse bands of darker. If over dead leaves, or on darker masses of rock, they are a violet brown, the transverse bands being nearly black. They harmonize so well with their surroundings that they are distinguishable by a careful examination only. The adults measure from $3\frac{1}{2}$ to $4\frac{1}{2}$ inches in length. In the waters where this fish occurs there is a small slender crayfish, of the same size and color, which is very easily mistaken for it. This crustacean has the same habit of lying for a long while in one position, then suddenly moving to another, and, if disturbed takes refuge under the banks or under stones in the same way. They may usually be distinguished by the fact that they move tail first, and then occasionally crawl slowly on the bottom; they also are much commoner near the sources of the rivers, above the range of the tri-tri.

In the dry season, the adult tri-tri migrate down stream to

the sea, where they lay their eggs, probably near the mouths of the rivers from which they descended,[1] and then apparently die, as no adult fish are ever seen to return.

The young fry, when about $\frac{3}{4}$ to $1\frac{1}{4}$ inches in length ascend the rivers by thousands during the wet season (August, September, and October), moving up stream in a continuous line near or under the banks, as do the young of eels (Anguilla). When in a stretch of comparatively quiet water they move steadily onward; but in rapid water they progress by jerks, resting on the bottom for a few seconds, then making a fresh dash onward and taking a fresh grip on a pebble or rock with the ventral sucker, and, after remaining quiet for a few seconds, dashing on again. They even ascend vertical or overhanging surfaces, over which a small amount of water is running in this way, resting for a while, then moving upward an inch or so, resting again, and moving on. Sometimes during one of these ascents they are swept off and into the eddy below; but in a few minutes they are ready to try it again. I have seen as many as a dozen moving up the face of a rounded rock a foot in diameter, over which the flow of water was not enough to cover their bodies. After a heavy rain the waters of the St. Vincent rivers rise rapidly, and then fall again, leaving many little outlying pools along the banks, which, under the influence of the scorching tropical sun soon dry up, leaving dusty hollows. Many of the fishes become cut off from the main stream at such times, and, as the pools dry up may be seen jumping about in the hollows, entirely covered with a thick coating of dust. If these stranded individuals be placed again in the main stream, they soon begin to ascend with the others as if nothing had happened. The tenacity of life of the young tri-tri is remarkable. They will live for several hours in these dry situations, exposed to the full rays of the sun.

The journey of the fry up the rivers occurs at the time when

[1] The fact that certain rivers in these islands, apparently suitable in every way for these fish are not inhabited by them seems to point toward the fact that the fish from the neighboring streams spawn in the vicinity of their mouths; otherwise we should expect to find a few of the young straying into these uninhabited streams every year.

the migratory shore birds from the north are making their brief stay in these islands, and certain species appear to feed largely on these fishes. On the Richmond River in St. Vincent, where, on account of the lack of vegetation, consequent on the late eruptions of the Soufrière, birds may be readily observed, I found the following species feeding on the young tri-tri. Near the mouth were blue herons (*Florida cærulea cærulescens*), golden plover (*Charadrius dominicus*), turnstones (*Arenaria interpres*), willet (*Symphemia semipalmata*), greater yellow-legs (*Totanus melanoleucus*), lesser yellow-legs (*T. flavipes*), solitary sandpipers (*Helodromas solitarius*), spotted sandpipers (*Actitis macularia*), green herons (*Butorides virescens maculata*), and kingfishers (*Ceryle alcyon*). The solitary sandpipers followed the fish up into the lowlands at the base of the hills, the green herons and kingfishers to the edge of, and even just within the forests, while the spotted sandpipers are found well up into the mountains. About the mouth of the river I also observed white herons (*Garzetta candidissima*), great blue herons (*Ardea herodias*), and fish hawks (*Pandion haliaëtus carolinensis*), probably attracted by the larger fish which were following the young tri-tri in from the sea, and which were abundant about the river's mouth.

On reaching the pools at the higher altitudes the fish select some suitable spot and there remain until maturity, when they return to the sea to deposit their eggs. I was unable to ascertain just how long this period was.

During their ascent of the streams, numbers of the young are caught by the natives and eaten, either boiled (whole) or fried into cakes. Although when cooked they bear a strong resemblance to maggots, they are very good, tasting something like whitebait.

These fish, or a closely allied species, are abundant in certain streams in Grenada, but are not found on the Grenadines. Their local name is a corruption of that given them by the original Caribs.

NOTES AND LITERATURE.

ZOÖLOGY.

Fishes and Ascidians. — The seventh volume of the now well established Cambridge Natural History [1] contains accounts of the fishes, ascidians, etc., and brings the series to within three of completion. This volume opens with a discussion of the Hemichordata by S. F. Harmer. Dr. Harmer's readable account of these very interesting animals presents a concise description of the habits, distribution, and anatomy of such forms as Balanoglossus, Cephalodiscus, and Phoronis; and concludes with a judicious summary of the evidence as to their affinities. Dr. Herdman contributes the article on the ascidians and amphioxus. This opens with a description of the anatomy of a typical ascidian, after which a general systematic consideration of the group is given. The chapter on amphioxus deals in a brief way with the habits, structure, and embryology of this important form. Here and there revised statements would have improved the text, as for instance those on the condition of the eye spots which were so admirably portrayed recently by Hesse. The commendable feature of illustrating geographical distribution by a chart is here marred by the fact that the signs used to represent Branchiostoma and Asymmetron are not printed with sufficient clearness to make them always unquestionable.

By far the larger part of the volume is given to the fishes, the general account of which comes from Dr. T. W. Bridge and the systematic part on the teleosts from Dr. Boulenger. Dr. Bridge's contribution is a safely conservative body of statement on the anatomy of fishes with a reasonable amount of natural history included in the systematic consideration of all groups except the teleosts. The account in the main is excellent but is marred here and there by insufficiency. Thus in dealing with the ear the author treats the organ as an unquestionable organ of hearing, omitting all mention of its equilibration function, the only function thus far known for it in such forms as the dogfish. Both Dr. Bridge's and Dr. Boulenger's

[1] *The Cambridge Natural History*. Vol. VII. Edited by S. F. Harmer and A. E. Shipley. Macmillan Co., New York, 1904. 8vo, xviii + 760 pp., 440 figs.

portions of the systematic account of the fishes are admirably illustrated and the accompanying charts of geographical distribution of families, etc., add much to the lucidity of the presentation. This volume is undoubtedly bound to rank high among its predecessors in this excellent series.

G. H. P.

Essays on Transformism. — Professor A. Giard[1] has collected and published in book form seven of his essays which appeared during the last twenty-five years and which all deal with evolutionary matters. The essays, which are in no essential respects changed from their original form, deal with the history of transformism, the embryology of ascidians and the origin of vertebrates, biology and taxonomy, the factors of evolution, Lamarck's principle and the heredity of somatic variations, convergence in pelagic forms, and animal symmetry; and afford a convenient collection for those interested in the evolutionary speculations of this well known French biologist.

G. H. P.

Morphology and Anthropology.[2] — The growth of anthropology particularly in its relations to morphology is well exemplified in the last number of the Cambridge Biological Series by Duckworth. The object of the volume is to set before the student a concise exposition of man's place in Nature as determined by natural history methods. The first part of the book deals with this question from the standpoint of comparative anatomy and describes in an abbreviated way the systems of organs in the mammals and especially in the primates, devoting particular attention to the crania and teeth. Then follows a condensed account of human embryology, after which anatomical variations are taken up. These fill the greater part of the volume, the last section of which deals with palæontological materials of importance to anthropology. The condensation of so much substance into so small a space often seriously interferes with an adequate treatment of the subject and one is often led to suspect that the volume may be found more acceptable to the student who is cramming for an examination than to the one who is seriously engaged in a real study of anthropology; nor does the preface sug-

[1] Giard, A. *Controverses Transformistes.* C. Naud, Paris. 8vo, viii + 180 pp., 23 figs.

[2] Duckworth, W. L. H. *Morphology and Anthropology.* Cambridge Biological Series, Macmillan & Co., 1904. 8vo, xxviii + 564 pp., 333 figs., 5 charts.

gest that this use of the book was far from the author's intentions. However commendable such a standpoint may be, it is almost invariably assumed to the detriment of the really serious study of the subject. As an examination compendium the volume has much to recommend it; but as a contribution to the science of anthropology it is much less satisfactory. The illustrations are numerous but often crude and harsh.

G. H. P.

Northern Plankton.[1]— The Hensen school of planktologists at Kiel have undertaken, under the leadership of Professor Karl Brandt, to issue a monograph of all the organisms found in the plankton of northern seas above 50° N. Associated with the editor-in-chief in this undertaking are twenty specialists, each an authority on the group of organisms with which he deals.

The literature which pertains to the complex of organisms composing the plankton is widely scattered and much of it inaccessible except in the large libraries at the great centers of learning. A comprehensive manual of the plankton will therefore be most welcome, not only to the biologist at the seashore who wishes to acquaint him self quickly with pelagic organisms, but also to the beginner who for the first time beholds the marvels of the "tow." The usefulness of this work is enhanced by the fact that nearly every species is represented by a "Habitusbild" or detail figure of diagnostic characters. Although limited in its scope to the fauna of northern and arctic seas, and based largely upon the investigations along the coasts of northern Europe, it is not a work of merely local interest, useful only within the limits of latitude which the editors have chosen, for the organisms of the plankton are in many cases cosmopolitan in their distribution and many species of the warm temperate Atlantic are carried by the Gulf Stream far beyond 50° N.

The work is to consist of twenty-one sections numbered in zoölogical and botanical sequence, each with independent pagination, and issued in parts as rapidly as the papers are prepared. Part I contains five of these sections, the pelagic tunicates by Drs. Borgert, Apstein, and Lohmann; the Ostracoda by Professor G. W. Müller

[1] Brandt, K. *Nordisches Plankton.* Lipsius & Tischer, Kiel and Leipzig, 1903. Erste Lieferung. Sect. III, 21 pp., 24 figs.; VII, 15 pp., 24 figs.; IX, 30 pp., 34 figs.; XIV, 32 pp., 33 figs.; XV, 52 pp., 56 figs. 1901. M. 6.—Zweite Lieferung. Sect. XI, 7 pp., 16 figs.; XX, 29 pp., 25 figs.; XXI, 40 pp., 135 figs. M. 3.60.

and the Cladocera by Dr. Apstein; the echinoderm larvæ by Dr. Th. Mortensen; the Foraminifera by Professor Rhumbler; and the Tripylea (= Phæodaria Hkl.) by Dr. Borgert. Part II contains the Ctenophora by Dr. Vanhöffen; the Schizophyceæ by Prof. N. Wille; and the Flagellatæ, Chlorophyceæ, Coccosphærales, and Silicoflagellatæ by Dr. E. Lemmermann.

As usual in works of composite authorship we find here considerable variety in the method and form of treatment, especially in matters of literature and synonymy. The admission of a large number of fresh-water species in the sections dealing with the Schizophyceæ, Chlorophyceæ, and Flagellatæ seems ill advised. They occur in brackish waters only and are generally adventitious even there, and have no part in the marine plankton. The authors of the sections dealing with the Ostracoda and Cladocera have excluded all adventitious forms from fresh water. It is to be hoped that the appearance of the remaining parts of this most useful manual may not be long delayed.

C. A. K.

Wild Birds and their Music.[1]— Notwithstanding the present-day abundance of popular guides to the study of our native birds, Mr. Mathews has found an almost untouched field in preparing a guide to the songs of the commoner species of the eastern United States. In this artistic little volume of 262 pages, the songs and characteristic notes of 82 species are carefully analyzed and set down in musical notation or in line and dot diagrams, and these are so explained as to be quite intelligible, even to one who has no technical knowledge of music. To the beginner in bird study, who finds it much easier to hear birds than to see them, this book cannot fail to be an aid in identifying the commoner song-birds. In addition to the musical description, a brief diagnosis of each species is added, together with a statement of its distribution. A number of plates in wash or in color illustrate nearly all the birds described in the text. All these are from drawings by the author, and although many of them are admirable, others have evidently suffered much in the reproduction. A good index enhances the value of this book for field use.

G. M. A.

[1] Mathews, F. Schuyler. *Field Book of Wild Birds and their Music.* New York; G. P. Putnam's Sons, 1904. 16mo, xxxv + 262 pp., illus. $2.00.

BOTANY.

New England Ferns and their Allies.[1]— This attractive little volume is intended as a popular guide to the New England ferns, club-mosses, and horse-tails. In a preliminary chapter, the various species are grouped first by their fruiting seasons, and then by the nature of their habitats. Each species is then described briefly and the more evident characteristics of closely allied forms are contrasted. Brief remarks follow on the general distribution, habit, and manner of fruiting. The descriptions are supplemented by one or more excellent illustrations of each species from photographs of fresh specimens. A key to the genera of the ferns treated, a glossary, and an index conclude this handbook. It is substantially bound and of a convenient size, and cannot fail to be of service to the increasing class of out-of-door folk who wish to know the names of the plants met with in their summer excursions.

G. M. A.

[1] Eastman, Helen. *New England Ferns and their Common Allies, an easy Method of determining the Species.* Boston and New York; Houghton, Mifflin and Co., 1904. 12mo, xxi + 161 pp., illus.

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